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Study of Solid Waste Management Alternatives for the City of Murray, Kentucky

CSI Resource Systems, Inc.
Boston, MA

Prepared for

Environmental Protection Agency
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This is STAGE I of a PHASE II technical assistance study to the City of Murray, Kentucky. The objectives were to assess current residential and commercial solid waste collection programs, examine solid waste collection system upgrading alternatives, evaluate the feasibility of solid waste baling and transfer, and to determine the potential market for discarded materials from a recovery program. Some of the conclusions are: a separation program has potential; recovery of aluminum is a high probability; markets for paper and ferrous metals do exist; the use of satellite vehicles would be more productive; curb-side collection is recommended; four person crews can be reduced to two; and a backdoor collection system would be more cost efficient.

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Solid Waste

EPA

A TECHNICAL ASSISTANCE PROGRAM REPORT

STUDY OF SOLID WASTE MANAGEMENT ALTERNATIVES FOR THE CITY OF MURRAY, KENTUCKY

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RESOURCE RECOVERY AND CONSERVATION PANELS

SEC. 2003. The Administrator shall provide teams of personnel, including Federal, State, and local employees or contractors (hereinafter referred to as "Resource Conservation and Recovery Panels") to provide States and local governments upon request with technical assistance on solid waste management, resource recovery, and resource conservation. Such teams shall include technical, marketing, financial, and institutional specialists, and the services of such teams shall be provided without charge to States or local governments.

This report has been reviewed by the Project Officer, EPA, and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the Environmental Protection Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

Project Officer: Elmer G. Cleveland

U.S. ENVIRONMENTAL PROTECTION AGENCY

TECHNICAL ASSISTANCE PROGRAM REPORT SERIES

STUDY OF SOLID WASTE MANAGEMENT ALTERNATIVES

FOR

THE CITY OF MURRAY, KENTUCKY

PREPARED FOR

OFFICE OF SOLID WASTE MANAGEMENT
U. S. ENVIRONMENTAL PROTECTION AGENCY
REGION IV, ATLANTA, GEORGIA

BY

ENGINEERING-SCIENCE, INC.
ATLANTA, GEORGIA

AND

CSI RESOURCE SYSTEMS, INC.
BOSTON, MASSACHUSETTS

OCTOBER 1979

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NOTES ON REPORT ARRANGEMENT

CHAPTERS

Roman Numerals were used for all chapters in this report. The pages within each section are numbered consecutively with Arabic numerals, preceded by the appropriate chapter number in Roman numerals. (Example: III-1, III-2, III-3, etc., for Chapter III).

TABLES

Tables are numbered using the same system as used for the chapters and are included in the text of which they are a part. (Example: Table III-1, III-2, etc.)

FIGURES

Figures are included at the end of each chapter and are numbered according to the same system as for Tables. (Example: Figure III-1, III-2, III-3, etc., for Figures in Chapter III).

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CHAPTER I

CONCLUSIONS

Phase II, Stage I of the technical Assistance to the City of Murray, Kentucky project has been completed. The objectives of tnis study were to assess current residential and commercial solid waste collection programs, examine solid waste collection system upgrading alternatives, evaluate the feasibility of solid waste baling and transfer, and to determine the potential market for discarded materials from a recovery program.

The information generated during this study and presented in this report forms the basis for the following conclusions:

1. The Murray residential refuse collection system as presently designed and operated with four-person crews is comparable on a per home cost basis to systems using two-person crews and offering the same nominal level of service. This conclusion is based on a comparison with two systems considered highly productive by the U. S. Environmental Protection Agency (U. S. EPA).

2. The Murray system as presently designed and operated with one driver and three collectors is more productive on a per crew basis, even though it is much less productive on a per collector basis than systems using one driver and one collector offering the same nominal level of service. This conclusion is based on a comparison with three systems considered highly productive by the U.S. EPA.

3. It is likely that a backdoor collection service could be established in Murray which would increase productivity and cost efficiency over the present system. Based on a cost estimate for an upgraded backdoor system with two-person crews, the annual savings that could be realized would not exceed $31,000 (22%), and would likely be considerably less.

4. Though no definitive statement can be made at this time, there are strong indications that the use of satellite vehicles for residential refuse collection in Murray increases collector productivity, but because of the added equipment expense does not decrease total collection costs.

5. The cost efficiency and productivity of the Murray residential solid waste collection system can be improved significantly by changing to curb-side collection and making changes in basic operating parameters.

6. A reasonable and attainable residential solid waste collection cost savings in the range of $44,000 to $50,000 per year (31-35%) can be achieved through the following system changes:

   - Change from backdoor pick-up to curb-side pick-up.
   - Reduce normal crew size to two persons.
   - Provide one 25 cu. yd. rear load packer truck per crew and eliminate the satellite vehicles.
   - Institute a rational task incentive program.
   - Change collection methodology to one side, two pass collection.

   These savings can be realized only if all personnel are performing their jobs competently and exhibiting a reasonable level of work effort.

7. The estimated <u>maximum</u> residential solid waste collection cost savings that can be attained as a result of basic system operation changes is in the range of 50% to 60%.

8. The estimated <u>maximum</u> increases in productivity that can be attained as a result of basic residential solid waste collection system changes are in the range of 40% to 50% on a "per crew" basis and in the range of 250% to 300% on a "per collector" basis.

9. The commercial solid waste collection program can be upgraded to include a combination of can and front-loaded bin pick-up at an anual cost which will be equivalent to or less than the cost for the presently used system.

10. Roll-off type container commercial collection service is not economically practical for the City of Murray given the present conditions and market for the service.

11. Solid waste transfer and large-scale transfer/baling systems are not economically practical for the City of Murray at this time.

12. At the scale being considered here, centralized separation of the recyclable components of the Murray mixed solid waste stream is not economically practical for materials recovery.

13. A recyclable materials source separation program has potential for successful use in the City of Murray.

14. Based on a limited market survey, it was determined that recovery of aluminum from solid waste in Murray has a relatively high probability of economic success at the present time.

15. Potential markets for ferrous metals and paper products exist, but economically successful recovery of these materials will be more difficult than it will be for aluminum.

16. Given the present market the probability of economically successful recovery of glass from solid waste in Murray is low.

CHAPTER II

INTRODUCTION

The City of Murray is located in Calloway County in the southwestern portion of Kentucky. Located in the city is Murray State University (MSU). It has been estimated that the current population of Murray is approximately 15,100 (see Appendix A) with about half of the population being students or teachers at the university. There are several industrial manufacturing plants in or near to the city.

Residential and commercial solid waste collection and disposal is performed by the Murray Department of Sanitation (MDS). The MDS currently employs about 24 persons.

The general objectives of this study were to examine present solid waste collection practices (residential and commercial) and to assess potential upgrading methods; to evaluate the feasibility of a centralized solid waste transfer or baling/transfer facility; and to investigate the potential for a recyclable discarded materials recovery program. The specific activities planned to accomplish these objectives are listed below:

1. Assess Alternative Curb-Side Collection Systems

   (a) Examine the present residential back-door solid waste collection system. Aspects to be investigated are crew utilization, routing, equipment, incentive system, schedules, and other productivity and cost affecting factors.

   (b) Review selected curb-side residential pick-up systems; and jointly with the Superintendent of Sanitation select a limited number of systems for further assessment.

   (c) Make an assessment of the selected curb-side systems in terms of equipment requirements, number and size of crews, alternative routings, and costs. Compare

with the existing back-door system, and identify a preferred system.

(d) Examine the impact of implementation of the preferred system on solid waste management program productivity and costs.

(e) Identify the steps and schedule associated with implementation of preferred residential curb-side collection system.

(f) Identify upgrading procedures for the commercial solid waste collection system.

2. Assess Feasibility of Central Baling, Materials Recovery, and Solid Waste Transfer

(a) Review and assess selected solid waste baling systems terms of capital outlays, total annual costs and areas for potential savings, if any, to the city compared with the present collection-disposal system.

(b) Identify potential locations for a baling facility and assess cost-effectiveness of each location, assuming a typical baling operation.

(c) Identify materials which could be recovered and determine the existence of potential buyers of the materials, and buyer specifications on the quality and quantity of recovered materials.

(d) Identify and assess methods for recovering candidate materials including source separation by households and businesses and centralized processing. Likely impacts on the potential central baling/transfer facility and on collection practices will also be defined.

(e) Identify procedures for use by the city in determining tonnage and composition of solid waste.

(f) Identify next steps and schedule (if appropriate) required to implement a materials recovery program.

CHAPTER III

EXISTING RESIDENTIAL SOLID WASTE COLLECTION SYSTEM

The objective of this chapter is to describe the existing residential solid waste collection system in Murray. The following subsections discuss system operations, facilities, management and equipment. A comparison of productivity and cost effectiveness is made between the present collection system in Murray and operating systems in other communities offering equilvalent service in the next chapter.

Description of the Existing System

The Murray Department of Sanitation (MDS) currently provides once per week, backdoor pick-up service to city residents (other than those living on campus at Murray State University) as well as a limited number of county residents (outside city limits). Some specific information about the system is given in Table III-1. The approximate, January 1, 1979 population of Murray was 15,100. Accounting for the out-of-city pick-ups and the on-campus students, the residential solid waste collection system serves approximately 12,200 people (see Appendix A for population estimates). Based on counts done by solid waste collection crews, approximately 4,300 residential collection stops are made per week.

Residential solid waste is collected by two 4-man crews. Each crew consists of one packer truck driver, two walkers, and one satellite vehicle driver/collector. During collection, the packer truck proceeds through residential areas on regular routes. The walkers use 44-gallon plastic barrels mounted on hand carts to collect refuse from the houses. This method saves the time of returning cans to their original location and requires less physical exertion from the walkers. The satellite vehicle operates in much the same manner with the exception that he can make several pick-ups before returning to the packer truck to unload. This vehicle is also utilized to collect from places where maneuvering the packer truck is difficult and the distance is excessive for the walkers (short dead-end streets, etc.).

TABLE III -1

PRESENT RESIDENTIAL SOLID WASTE COLLECTION

SYSTEM INFORMATION - MURRAY, KENTUCKY

SERVICE

Collection per resident per week - 1
Landscaping wastes are collected along with household refuse
Pick-up location - backdoor
City Population - 15,100(1)
Population served - 12,200(2)
Residential pick-ups - 4,300/wk

COLLECTION SYSTEM

Crews - 2
East Crew - 1 driver, 2 walkers, 1 satellite vehicle driver/collector
one 25-cu. yd., rear-load packer truck
one 1.6-cu. yd., 3 wheel satellite collection vehicle

West Crew - 1 driver, 2 walkers, 1 satellite vehicle driver/collector
one 18-cu. yd., rear-load packer truck
one 1.6-cu.yd., 3 wheel satellite collection vehicle

Collection Methodology - both sides of street on one pass

Incentive System - None (8 hr. work day)

Containerization - Bags, cans (not strictly enforced)

Approximately 4.5 days per week are required to complete residential methodology.

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(1) See Appendix A for population estimates
(2) Adjusted for out of city collections made and university collections not made.

The collection personnel in Murray work on an 8-hour day system. Generally, Monday through Thursday collections are finished in 7 to 7.5 hours. Friday collection is scheduled such that the crews are finished by noon. The crews spend Friday afternoons cleaning the collection vehicles, collecting refuse from missed stops, etc..

The Department of Sanitation's regulations allow bag or can containerization. It was estimated that roughly 25% bags, and 70% cans are used by the residents of the city (by count). The remaining 5% of the containers used consist of bundles, carboard boxes, buckets, etc. The regulations require the refuse cans to be a minimum of 20-gallon capacity and a maximum of 32-gallon capacity. The total quantity of refuse collected per week per household is not to exceed 96 gallons. Route surveying has shown that there is compliance with the regulations in most cases.

The MDS currently collects landscaping waste (grass clippings, etc.) along with household refuse. Special pick-ups of large bulky items are also provided on an as-requested basis. These pick-ups are not made as part of regular residential collection activities.

Cost and Productivity Analysis of Existing System

As part of the analysis of Murray's existing solid waste collection program, an estimate of real system costs was made. This estimate is based on long term continuation of the present system with eventual replacement of the 18-cu. yd. packer truck by a 25-cu. yd. packer truck (i.e., both crews using 25-cu. yd. packers). It was assumed that financing charges would be incurred. The costs were put in terms of 1979 dollars and are based on the current pay scale and current equipment prices. The results of this analysis are presented in Table III-2. Details of the cost analysis are given in Appendix B.

As of this time, there is not enough data available to accurately determine the average weight of residential solid waste collected per day in Murray. To compile this information would require weighing of the full collection vehicles frequently during a year long period (to account for

TABLE III-2

PER-CREW COST FOR RESIDENTIAL SOLID WASTE COLLECTION SYSTEM OPERATION - MURRAY, KENTUCKY(1)

Equipment(2)

1-25 cu. yd packer truck + 1.6 cu. yd satellite vehicle
Cost per occupied hour = $14.8/hr
Occupied time per week = 34 hr/wk
Total annual equipment cost (52 wk) = $26,166/yr

Labor(3)

1 - packer truck driver, 2 walkers, 1 satellite driver/collector
Labor cost of crew = $21.7/hr
Paid time = 40 hr/wk
Total annual labor cost (52 wk) = $45,136/yr

Total Operation Cost = $71,300/yr

(1) See Appendix B for cost estimates - 1979 $

(2) Includes capital, debt service, insurance, fuel, maintenance, down time and obsolescence.

(3) Includes wages, fringe benefits and personnel overhead

seasonal variations). This task is beyond the scope of this study and the equipment capability of the MDS. Based on data obtained from other studies and reported in the literature, there is quite a bit of fluctuation in the rate of household solid waste production between various communities. The rate of production appears to be a function of population density, economic affluency, and region of the country. Based on consideration of the characteristics of Murray the average residential solid waste production rate is probably in the range of 2.2 to 3.0 lb/person-day (7-day basis including landscaping refuse). For the purposes of this study, the long term (year-round) average will be assumed at 2.7 lb/person-day (7-day basis). Given the population of 12,200 persons served by the MDS (see Table III-1) the total weight of household and landscape refuse produced is approximately 16 tons/day (7-day basis). This figure is consistent with the one (1) measurement thus far taken by the MDS.

The information contained in Table III-3 was derived from data collected by the MDS crews. The data for the East crew will be used for operation analysis; however, both sets are presented to illustrate the difference caused by the packer truck capacity. It can be seen that for the same number of active hours, the crew with the larger packer spends approximately 5% more time productively (involved in collection) and makes about 160 more pick-ups per week. The crew with the larger packer is also free about 1.4 more hours per week to make extra and missed pick-ups and to wash the collection vehicles. The difference is due to the fact that the smaller truck must make 4 extra trips to the landfill each week.

Table III-4 shows a summary of daily costs, task costs, and productivity factors for the Murray solid waste collection system. These figures were developed from the cost estimate given in Appendix B and data obtained by collection crews. This information will be discussed and used for comparative purposes in the next chapter.

Satellite Vehicle Productivity and Cost Efficiency

The objective of this subsection is to compare the cost efficiency and productivity of the two methods used by the MDS residential collection

TABLE III-3

TIME SPENT ON VARIOUS SOLID WASTE COLLECTION TASKS[1]

Activity	East Crew (25 cu. yd. packer, 1 trip to landfill/day)	West Crew (18 cu. yd. packer, 2 trips to landfill/day)
Weekly		
Total paid time	40 hr/wk	40 hr/wk
Time spent:		
To route	0.5	0.9
Collecting	26.6	25.3
Transfer to landfill	3.9	6.2
Scheduled breaks[2]	1.6	1.6
Other [3]	7.4	6.0
Approximate collection pick-ups	2230/wk	2070/wk
Daily[4]		
Total paid time	8 hr/day	8 hr/day
Time spent:		
To route	0.10	0.17
Collecting	5.76	5.44
Transfer to landfill	0.78	1.37
Scheduled breaks[1]	0.32	0.31
Other[2]	1.04	0.71
Approximate collection pick-ups	490	441
Walkers only	287	267
Satellite vehicle only	203	147

(1) Data collected for purposes of this study.

(2) On route breaks for which employees are paid; does not include lunch.

(3) Extra and missed pick-ups, vehicle washing, early release from work.

(4) Based on measurements for full collection days over a three week period (i.e. Monday through Thursday).

TABLE III-4

SOLID WASTE COLLECTION SYSTEM

COSTS AND PRODUCTIVITY - MURRAY, KY.

Daily cost for collection (full collection days) Equipment	$111/day
Labor	$174/day
Total	$285/day
Cost to route(1)	$4.3/day
Cost to collect(1)	$249/day
Cost to transport to landfill(1)	$33.7/day
Total cost per home served	$0.58/wk
Collection cost per home served	$0.51/wk
Total cost per ton collected	$21.6/ton
Collection cost per ton Collected(2)	$18.8/ton
Homes served per crew per collection hour	85
Homes served per collector per collection hour	28
Tons collected per crew per collection hour	2.3
Tons collected per collector per collection hour	0.8

(1) Total daily cost adjusted by ratio of task time to total working (not paid) time.

(2) Based on 13.2 ton/day collected per crew; See Appendix B.

crews to transport refuse from the placement location (backdoor, side of house, etc.) to the packer vehicle.

1. Walkers (two on each crew)
2. Satellite vehicle (used here to refer to the satellite vehicle/driver combination).

The results will give a good indication as to whether the use of the satellite vehicle contributes to or detracts from crew collection efficiency. It must be remembered that there are situations that each method is better suited for than the other. For example it could require a long walk by the walkers (or a u-turn for the packer vehicle) to collect the refuse from a short dead-end street with only a few houses on it. The satellite vehicle would be well suited for this type of situation. On the other hand, collecting from homes where the refuse containers are placed in a fenced backyard would require a satellite vehicle driver to leave his vehicle and walk through the gate just as walking collectors would. In this case the satellite vehicle would probably not be any more efficient than a walker with a rolling tote barrel and could very well be less efficient. The point is that each method has its own advantages and one collection method will probably not be as productive as the other in all collection situations.

The information given in Table III-5 is based on collection stop counts made by the MDS crews and labor and satellite equipment costs estimated in Appendix B. It can be seen that the teams of walkers for the two crews (East and West) are equally productive; each serving about 50 homes per collection hour. The satellite vehicle on the East crew, however, is a little more productive than the satellite vehicle on the West crew. In both cases the walker teams are about 50% more productive than the satellite vehicles. When considering personal productivity (homes served per collector per collection hour) it can be seen that the satellite drivers are about 20 to 40% more productive than the individual walkers. The estimated loading costs (defined here as the total cost for transporting the refuse from the placement location to the packer vehicle) for the two methods are also presented in Table III-5. In the case of the East crew the satellite vehicle appears to be slightly more cost efficient than the walkers ($\sim$3%) but in the case of the West crew the

TABLE III-5

COMPARISON BETWEEN WALKER AND SATELLITE VEHICLE

PRODUCTIVITY AND COST EFFICIENCY

	East Crew		West Crew	
	Two Walkers	Satellite Vehicle and Driver	Two Walkers	Satellite Vehicle and Driver
Homes served per collection hour[1]	50	35	49	32
Homes served per collector per collection hour	25	35	25	32
Loading cost per home served[2] ($/wk)	0.30	0.29	0.32	0.34

(1) Based on measurements for full collection days over a three week period.

(2) Loading cost is the total cost for transporting the refuse from the placement location (backdoor, side of garage, etc.) to the packer truck and loading it. The cost for the packer vehicle and driver is not included (constant for each crew).

walkers are a little more cost efficient than the satellite vehicle (~6%). The level of cost estimate done here and the amount of data obtained were not sufficient to guarantee these small differences and it will be assumed that for practical purposes the two collection methods are equivalent on a cost efficiency basis. The reason that the costs are more or less equivalent is that though the personal out-put is higher for the satellite driver than for each of the walkers, when vehicle costs are included it costs about the same per home to use two people for collection.

Though no definitive statement can be made at this time, the indications in this case are that the use of the satellite vehicles improves average personal (per collector) and per crew productivity, but their use does not result in any significant cost savings. Absolute proof of this statement would require making normal collections over an extended period of time with three walkers and no satellite vehicle to obtain information for comparison with the system as presently operated.

Existing Collection Routes

As previously stated, Murray residential solid waste collection is done by two crews (East and West). The crews follow regular paths during each day of collections. These regular paths have "evolved" as areas of service were annexed. Table III-6 shows daily mileages driven to route, on route, to lunch (crews return to motor pool for lunch) and to landfill for both crews. It can be seen that over the entire week the distance traveled by each crew on route and to route is comparable. The West crew travels about 10 miles more per week for lunch breaks. The distance traveled to the landfill is about 60 miles per week greater for the West crew that for the East crew. This is due to the fact that the West crew must make four more trips to the landfill per week.

Also given in Table III-6 is the approximate number and type of turns made by each crew on route. It can be seen that the East crew makes approximately 50% left turns and 50% right turns but the West crew makes about 25% more right turns than left turns. In general, left turns are more costly and time consuming than right turns.

TABLE III-6

EXISTING SOLID WASTE COLLECTION SYSTEM ROUTE INFORMATION - MURRAY, KENTUCKY

		Travel Distances					On-Route Turns		
		To Route (mi)	On Route[1] (mi)	Lunch Round Trip (mi)	Landfill Round Trip (mi)	Total	Right	Left	U-turns
East Crew:	Mon.	1.6	14.0	2.7	15	33.3	19	11	1
	Tues.	1.0	4.3	3.1	15	23.4	6	7	2
	Wed.	1.8	8.2	5.1	15	30.1	12	8	1
	Thurs.	3.3	7.5	6.7	15	32.5	11	13	3
	Fri.[2]	3.3	4.0	--	15	22.3	3	11	0
Total		11.0	38.0	17.6	75	142.0	51	50	7
%		8	27	12	53	100	47	46	6
West Crew:	Mon.	0.5	9.2	4.4	30	44.1	13	10	1
	Tues.	2.4	7.3	6.2	30	45.9	12	7	2
	Wed.	3.5	6.2	8.3	30	48.0	8	8	0
	Thurs.	4.7	8.6	9.0	30	52.3	16	5	0
	Fri.[2]	3.7	4.6	--	15	23.3	11	5	0
Total		14.8	35.9	27.9	135	214.0	60	35	3
%		7	17	13	63	100	61	36	3

(1) Does not include miles driven in mobile home parks.

(2) Does not include miles driven for extra and missed pick-ups

As previously stated, the present residential collection routes have evolved as new areas of service were annexed and thus were not systematically designed for the current total area of service. There is a high probability that more efficient routing of the collection paths would contribute to residential collection crew productivity. At this time it is impractical to make the efforts required to quantify the productivity increases and resulting cost savings that would occur through more efficient routing.

CHAPTER IV
COMPARISON OF EXISTING SYSTEM WITH OTHER SYSTEMS OFFERING EQUIVALENT SERVICE

The objective of this chapter is to compare the performance of the Murray solid waste collection system with other systems that have been subjects of study. The results will give an indication of the relative efficiency and productivity with which the Murray system was designed and is being operated.

Description of Systems to be Compared

Table IV-1 gives the system characteristics for four residential solid waste collection programs (Murray plus three other systems). Systems G and H were the subjects of a year-long EPA sponsored study of "highly productive" solid waste collection programs. The systems described in Table IV-1 vary from each other in terms of crew size, type of equipment used and incentive system. The systems are similar in that they are all publicly owned and offer equivalent levels of service. The important similarity that makes them comparable on certain terms is that they all offer the same nominal level of service; i.e. the customers for each system receive the same type and frequency of service. All systems collect once per week from the container storage location (back door, side of garage, etc.) with the customers using the same type of container. These are the factors that have a direct effect on the customer, excluding service charges. Because of the fact that none of the systems described in Table IV-1 are designed and operated in exactly the same way, any comparison made between them must be a comparison based on a combination of both operating and design efficiency.

Method of Analysis

The cost analysis assumed continuation of the Murray system as is for an indefinite period of time. Eventual use of 25-cu.yd, packer trucks for both crews (rather than one 25-cu. yd. and one 18-cu. yd.) was also assumed. The cost estimate was based on the current MDS pay scale and

TABLE IV-1

CHARACTERISTICS OF COMPARABLE SOLID WASTE COLLECTION SYSTEMS

System	Operating Agency	Type of Equipment[1]	Crew Size	Collections Per Week	Point of Collection	Collection[2] Methodology	Incentive[3] System	Union Rep.	Containerization: Refuse Bags (%)	Cans (%)	Misc. (%)
Murray	Public	25-RL 1.6-S	4	1	Backyard	One Pass	None	No	25	70	5
G[4]	Public	20-RL	2	1	Backyard	One Pass	Task	No	2	90	2
H[4]	Public	13-RL	2	1	Backyard	One Pass	None	Yes	33	55	12
T.W.[5]	Public	--	2	1	Backyard	--	Task	--	--	--	--

(1) 25-RL = 25 cu. yd., rear loaded packer; 1.6-S = 1.6 cu. yd. satellite vehicle, etc..

(2) All systems one pass with tote barrel

(3) None indicates crews are required to work 8 hr./day; task indicates that crews may leave when collection and other assigned tasks are completed.

(4) EPA Study System

(5) Tacoma, Washington system. Information provided by John Thompson, U. S. EPA, Washington, D. C.

current equipment prices (as estimated by vendors). The details of this cost estimate are given in Appendix B.

A data collection program was initiated by Mr. Jerry Wallace (Superintendent of Sanitation, MDS) and ES staff and performed by the MDS collection crews. The data collected made it possible to determine average times utilized for the performance of collection related tasks. Other information obtained included homes served, collection vehicle mileage, and fuel utilization, The results of the analysis of this data, along with the results of the cost estimates, were used to calculate cost effectiveness and productivity factors for the present Murray residential solid waste collection system.

Normalized cost information for the systems to be compared with Murray was calculated. These calculations utilized equipment costs that are comparable to Murray's equipment costs and the MDS pay scale (see Appendix C). The results are normalized daily operating costs for the Comparison Systems that are directly comparable with the estimated operating cost for the Murray System. Using productivity factors measured during actual operation over a year-long period, the "per home served" and "per ton collected" costs for systems G and H were calculated. Direct comparison of these costs with those calculated for the Murray system will give a measure of the relative cost efficiency with which the Murray system is currently operating.

Cost Efficiency and Productivity Comparison

A comparison of cost and productivity factors between the four solid waste collection systems is given in Table IV-2. It can be seen that on a cost per home basis the Murray system is economically less efficient than system G but is more efficient than system H. System H is operated on a eight hour day basis and the collection crews are unionized, whereas system G is operated with a task incentive system and crews are not unionized. System G also has a much lower weight per home production rate. When considering productivity on a per home served basis the Murray system is the most productive by crew, however, because its crews are larger than the others it is the least productive by collector (walker).

TABLE IV-2

COMPARISON OF COST AND PRODUCTIVITY FACTORS

OF SYSTEMS OFFERING EQUIVALENT LEVELS OF SERVICE

Cost Factors (1)	System Murray	G	H	T.W.
Total daily cost ($/day)	285	179	158	-
Daily cost for collection ($/day)	249	139	123	-
Homes served per day	490	372	233	-
Tons collected per day(3)	13.2	6.2	5.7	-
Pounds collected per home per wk	54	33	51	-
Total cost per home served ($/wk)	0.58	0.48	0.68	-
Collection cost per home served ($/wk)	0.51	0.37	0.53	-
Total cost per ton collected ($/ton)	21.6	28.9	27.7	-
Collection cost per ton collected ($/ton)	18.8	22.5	21.6	-
Productivity Factors				
Homes served per crew per collection hr.	85	72	45	49
Homes served per collector per collection hr.(2)	28	72	45	49
Tons collected per crew per collection hr.	2.3	1.2	1.1	1.2
Tons collected per collector per collection hr.(2)	0.8	1.2	1.1	1.2

1) Costs have been normalized and are on a comparable basis. For normalization procedure see Appendix C.
2) For Murray system and systems G and H the driver does not normally perform refuse loading. The available data for the T.W. system does not specify whether or not the driver helps with loading on a regular basis.
3) Murray based on estimated weight; others based on measured weights.

Based on tonnage collected, the factors given in Table IV-2 indicate that the Murray system is more efficient on economic ($/ton) and productivity (ton/crew-hr) basis. The information presented in the table indicates that the Murray productivity per collector is less than the other systems. As previously stated, the Murray weight basis refuse collection rates were estimated from an assumed personal refuse production rate factor. Though this represents a reasonable method of estimation under the given circumstances, there is a good possibility that the actual rate in Murray is significantly different from the one assumed. Table IV-3 presents actual refuse production rates for a number of communities (based on weight measurements taken over an extended period of time). It can be seen that the values range from 33 to 71 lb/home-wk with the mean being 54 lb/home-wk. The standard deviation is ± 22% of the mean for this data. This data is valid and illustrates the variability being discussed here. Keeping this high variability of refuse production rate in mind, it can only be concluded that no definitive statement can be made concerning the per ton productivity or per ton cost effectiveness of the Murray system.

Conclusions that can be drawn from the material and discussion presented in this chapter are:

1. The Murray residential refuse collection system as presently designed and operated is comparable on a per home cost efficiency basis to systems using smaller collection crews and offering the same nominal level of service. This conclusion is based on a comparison with two highly productive systems using two-person crews.

2. The Murray residential refuse collection system as presently designed and operated is more productive on a per crew basis but much less productive on a per crew person basis than systems using smaller collection crews and offering the same nominal level of service. This conclusion is based on a comparison with three highly productive systems using two-person crews.

3. Because actual collected solid waste tonnage measurements have not been made, it is not possible to make a definitive statement as to the per ton cost efficiency or productivity for the Murray system.

TABLE IV-3

COLLECTED SOLID WASTE PRODUCTION RATES FOR A NUMBER OF COMMUNITIES

System[1]	Solid waste produced per home[2] (lb/home-wk)
Murray[3]	54
A	46
B	71
C	49
D	51
E	62
F	65
G	33
H	51
Mean[4]	54
Standard deviation[4]	12

(1) Systems A through H were subjects of year-long EPA study (EPA/530/SW-97c.1).

(2) All except Murray based on weighed tonnage.

(3) Based on estimated 2.7 lb. household waste generated per person per day (7-day basis).

(4) Not including Murray.

Potential Productivity and Cost Efficiency Increases with an Upgraded Backdoor Collection Service in Murray

The previous sub-section presented material concerning the relative differences in cost efficiency and productivity between the Murray residential solid waste collection system and several other systems which use smaller crews and offer the same nominal level of service. It was shown that of the three systems that were compared on a cost per home served basis, that the Murray system was more cost efficient than one (system H) but less cost efficient than the other (system G).

If the Murray system was upgraded to a design similar to system G and was able to attain the same productivity as system G some cost savings could be incurred. Table IV-4 gives cost estimates for the Murray residential refuse collection system and for the upgraded backdoor collection system similar to system G. For the purposes of this estimate it was assumed that 25 cu. yd. collection vehicles would be used for the upgraded system (system G actually uses smaller vehicles). It can be seen that approximately $31,000 per year (22%) could be saved with the upgraded system. There are many factors which affect crew and collector productivity. Some are difficult to quantify such as distance from street to point of refuse placement and street parking practices. Others, like solid waste production per home (weight basis), are more readily identifiable. It can be seen from Table IV-3 that system G, the one being used to simulate an upgraded Murray system, has the lowest refuse production rate of all the systems listed (61% of the mean; 46% of the maximum). Though the true residential refuse production rate is not now known for Murray, it is very probable that it is not this low. Based on this presumption it is unlikely that the productivity experienced with system G could be reproduced in Murray. It is highly probable that some increases in productivity and cost efficiency could be realized by re-routing and other changes to the Murray backdoor collection system but it is unlikely that these improvements would result in cost savings as high as 15%. Thus it will be assumed here that the 15% cost savings represents the upper limit of what can be accomplished while providing backdoor pick-up in Murray.

TABLE IV-4

COST ESTIMATES FOR THE PRESENT MURRAY RESIDENTIAL COLLECTION SYSTEM AND AN UPGRADED BACKDOOR SERVICE SYSTEM

	Present Murray System	Upgraded Murray[1] System
Number of homes to be serviced per week	4,300	4,300
Number of homes which can be served per day, 2 crews	980	829
Number of days per week required for collection, 2 crews	4.4	5.2
Total daily collection crew cost, 2 crews	$570/day	$367/day
Total weekly collection crew cost, 2 crews	$2,508/wk	$1,908/wk.
Annual collection crew cost, 2 crews	$130,416/year	$99,216/year
Cost for collection related extras, 2 crews[2]	$12,184/year	$12,184/year
Estimated total annual cost	$142,600/year	$111,400/year
Estimated annual savings over present system	---	$ 31,200/year
Percent saved	---	22%

(1) Upgraded system similar to system G using 25-cu. yd. packer vehicle.

(2) Vehicle washing, missed pick-ups, etc.

CHAPTER V

SELECTION OF PREFERRED SYSTEM CHANGES FOR THE MURRAY RESIDENTIAL SOLID WASTE COLLECTION SYSTEM

Introduction

The objective of this chapter is to present information on the cost reductions and productivity increases that can be realized by operating and/or equipment changes to the Murray residential solid waste collection system. The present general objectives of the MDS management are as follows:

1. To reduce the level of service to the residential customers to curb-side collection (as opposed to the backdoor collection currently provided).
2. To maintain once per week residential collection.
3. To provide the collection service at a minimum cost, with appropriate consideration for convenience, health and safety.

Information is presented in this chapter which will be used to quantify the cost efficiency and productivity increases that can result in changes in the following areas:

a. Equipment type
b. Crew size
c. Point of pick-up
d. Collection methodology
e. Incentive system

The information presented here for comparative purposes was obtained from full scale refuse collection systems under normal operating conditions. It is believed that the results represent a realistic approximation of benefits that can be obtained with the Murray system. The final sub-section of this chapter presents a preferred system which will be further discussed in Chapter VI.

Description of Comparison Systems

Operating conditions of the residential solid waste collection systems that will be used for comparison with the Murray system are given in Table V-1. The operating conditions for the Murray system are also shown. The systems (A through F) will be referred to as the Comparison Systems. These systems were the subject of a year-long EPA sponsored study reported on in March, 1975[1]. The systems were chosen as being "highly productive" and only the four most productive routes from each system were studied. The results are what the EPA study considers "a valuable tool for appraising the productivity and cost efficiency of (other operations)". The Comparison Systems will be used as a standard from which cost efficiency and productivity increases will be estimated as a result of operational and/or equipment changes to the Murray system. Due to the fact that the Comparison Systems are highly productive, estimated increases in cost efficiency and productivity for the Murray system assume a reasonably high level of competency and work effort on the part of all personnel.

Collection Methodology

It was originally planned to examine the potential differences that could occur from altering collection methodology (i.e. one side of street, two pass collection versus two side of street, one pass collection) for the Murray system as an independent variable. That is, several pairs of alternative collection system operation methods were to be examined with the only difference between the members of each pair being the collection methodology. Subsequent analyses have made it evident that the isolated effect of collection methodology change in cost efficiency and productivity is difficult to quantify. This is partially due to the fact that the majority of current practice conforms to the following basic guidelines:

1. In cases where there is only one collector the collection methodology is one side of street, two pass. This would apply to the case where there is a two person crew (one driver, one collector) and to the case where there is one person crew (one driver/collector).

TABLE V-1

OPERATING CONDITIONS OF COMPARISON

SOLID WASTE COLLECTION SYSTEMS

Collection[1] System	Operating Agency	Type of Equipment	Crew Size	Frequency of Collection	Point of Storage	Collection Methodology	Incentive[2] System	Type of Storage Container	Union Representation
A	Public	Side Loader	1	1/week	Curb-alley	1 Side of St.	Task	Bags & Cans	No
B	Public	Side Loader	1	1/week	Curb-alley	1 Side of St.	None	Bags & Cans	No
C	Private	Rear Loader	2	1/week	Curb-alley	1 Side of St.	Task	Bags & Cans	Yes
D	Public	Rear Loader	2	1/week	Curb-alley	1 Side of St.	None	Bags & Cans	Yes
E	Public	Rear Loader	3	1/week	Curb-alley	Both Sides	Task	Bags & Cans	Yes
F	Public	Rear Loader	3	1/week	Curb-alley	Both Sides	None	Bags & Cans	Yes
Murray	Public	Rear Loader, Satellite	4	1/week	Backdoor	Both Sides	None	Bags & Cans	No

(1) All but Murray are previous EPA study systems[1]

(2) None - 8 hour day is worked

Task - Crews are allowed to leave work as soon as collection and other specific tasks are completed.

2. In the cases where there are more than two collectors the collection methodology is two sides of the street, one pass. This would apply to the case where there is a greater than three person crew (one driver, more than two collectors) and the case where there is a three person crew (one driver/collector, two collectors).
3. In the case where there is a three person crew (one driver and two collectors or a two person crew (one driver/collector and one collector) there is a practical choice between the two collection methodologies.

The logic behind these guidelines assumes that it is awkward for one collector or driver/collector to collect from both sides of the street and more than two collectors can not significantly speed up operations when only one side of the street is being picked-up. This logic is discussed briefly in the report from which the Comparison Systems information was taken[1]. There are certain specific situations that do not conform to the logic upon which these guidelines are based. An example would be the case where a crew with more than two collectors is picking up a wide street with heavy traffic. It was assumed for the purposes of this report, however, that the previously stated guidelines are sound, and represent the most usable and efficient general relationship between crew size, crew-person task, and collection methodology.

Presentation and Discussion of Cost Efficiency and Productivity Data

The objective of this section is to present and discuss the cost efficiency and productivity information for the Comparison Systems as well as the Murray system. It should be remembered that any comparison between the Murray system and the Comparison Systems cannot be taken as a strict comment on the Murray system's operational efficiency. There exists the basic difference that the Murray system currently collects from the back-door of the served homes while the Comparison Systems collect from the curb. Research has shown that the point of refuse placement is the factor that has the single greatest impact on collection cost efficiency and productivity. Its impact on productivity is about 1.5 times the impact of the second most influential single factor (crew size). Its impact on cost efficiency is almost 1.9 times the impact of the second most influential single

factor (frequency of collection)[1]. Thus, the comparisons made here are for the purpose of illustrating and quantifying savings and productivity increases that can result from a switch to curb-side collection and other operations changes for the Murray system.

Table V-2 presents cost efficiency and productivity factors for the Comparison Systems as well as key operational parameters and explanatory variables. The productivity and cost efficiency factors are also graphically represented in Figures V-1, 2, and 3.

Figure V-1 and Table V-2 present the cost factors for the systems being compared. These factors are in terms of cost per home served ($/home-wk) and cost per ton collected ($/ton). It can be seen that the Comparison Systems can be divided into pairs (A-B, C-D, and E-F). The operating conditions for the pairs of systems are the same with the exception that one of the systems in each pair is operated with an incentive system (task) and the other is not. For two of the three Comparison System pairs (A-B and E-F) there is a marked decrease in per home and per ton cost for the task system over the other. For the C-D pair the task system is less cost efficient than the other (though they are comparable on a per home basis). One cause for this might be that the containerization for System D was 85% bags while the containerization for system C was 56% bags. Bags are usually quicker and easier to load than cans. The Murray system is comparable to system F for both per home and per ton costs, but is less cost efficient than all the other systems presented. It should be noted that while the per ton costs for the Comparison Systems are based on actual weight measurements, the per ton costs for the Murray system is based on an assumed solid waste production rate factor. A large amount of variation in this rate has been observed for different communities. The per ton information for the Murray system should thus be taken as a rough estimate only. The most cost efficient of the systems are systems A (one person, one pass) and D (two persons, one pass).

Figure V-2 and Table V-1 present per crew productivity information. When considering homes served per crew per hour it can be seen that system D is the most productive. Systems A, C, and E, are all equally productive

TABLE V-2

COST AND PRODUCTIVITY SUMMARY

FOR MURRAY AND COMPARISON SYSTEMS

System	Operation Parameters				Key Cost and Productivity Factors			Explanatory Variables	
	Point of Pick-up	Crew Size	Collection Methodology	Incentive System	Homes Served Per Crew Per Hour	Homes Served Per Collector Per Hour	Cost Per Home Served ($/wk)	Containerization (% Bags/% Cans)	Refuse Production (lb/Home-wk)*
A	Curb	1	Two pass	Task	107	107	0.23	34/52	46
B	Curb	1	Two pass	None	56	56	0.44	26/53	71
C	Curb	2	Two pass	Task	107	107	0.33	56/28	49
D	Curb	2	Two pass	None	123	116	0.26	85/6	51
E	Curb	3	One pass	Task	107	52	0.40	56/28	62
F	Curb	3	One pass	None	68	34	0.58	25/47	65
Murray	Backdoor	4	One pass	None	85	28	0.58	25/70	54

* Factor for Murray is estimated. All others based on measured weights.

(all three being a little less productive than D). The Murray system is more productive than systems B and F on the basis of homes served per crew per hour but is comparable with system F. System E is the most productive of the systems as far as tons collected per crew per hour (lower chart on Figure V-2). System D is slightly less productive at 3.1 ton/crew-hr. with all the other systems falling in the range of 2.0 to 2.6 ton/crew-hr. As previously noted the per ton measure of productivity for the Murray system is only an estimate.

Productivity on a per collector basis is shown in Figure V-3 and Table V-2. Systems A, C, and D are the most productive of the systems by this measure. The Murray system is the least productive of all the systems by collector. This stems from the fact that, though competitive with the others on a per crew basis, the Murray crews are larger than the others and are thus less productive on an individual crew member basis.

The conclusions in this section and the cost and productivity information presented in Table V-2 and Figures V-1 through V-3 are as follows:

1. The cost efficiency and productivity of the Murray solid waste collection system can be improved significantly by a change to curb-side pick-up and other system operation changes (assuming a reasonably high level of competence and work effort on the part of all personnel).

2. Based on the information presented in this section, the estimated maximum reduction in solid waste collection crew operating costs that can be realized as a result of operating changes (encompassed by the variables listed in Table V-1) is in the range of 50 to 60%.

3. Based on the information presented in this section, the estimated maximum increase in solid waste collection crew productivity that can be realized as a result of operating changes (encompassed by the variables listed in Table V-1) is in the range of 40 to 50% on a per crew basis and 250 to 300% on a per collector basis.

Definition of Preferred System

As previously discussed, the present objectives of the MDS management are to reduce the level of service provided by the Murray residential solid waste collection system to curb-side pick-up and maintain once per week per house collection at the lowest possible cost with appropriate consideration for convenience, health, and safety. The information that was presented in the previous section was used to predict the maximum obtainable residential collection cost decreases that can be expected from the types of system variations being considered for the Murray system.

The system variation alternatives that were considered and the estimated resulting maximum cost savings that can be expected are presented in Figure V-4. It should be kept in mind that these savings are estimated maximums and will require a reasonably high level of competency and work effort on the part of all personnel in order to be realized. It is estimated that about 30% of the collection costs can be saved by operating with the present type of equipment, crew size, and collection methodology (i.e. one pass collection). This savings would result from requiring curb-side placement of refuse containers and elimination of unused personnel and equipment (Alternative II). An estimated additional 6% of the collection costs can be eliminated (36% total) by reducing the collection crew size to 3, eliminating the satellite vehicle, and developing a rational task incentive program (Alternative III). Again, idle equipment and personnel must be eliminated. Cost savings can be increased to as high as 54% by further reducing the crew size to two, collecting from one side of the street at a time, and eliminating non-used personnel and equipment (Alternative IV). A maximum of 58% could be saved by reducing crew size to one and replacing the currently used rear load packer trucks with side-loaded, right-hand drive vehicles (Alternative V).

Based upon the MDS management's current objectives and the results of the cost comparisons previously made, the following changes to the Murray residential solid waste collection system are suggested as the preferred system:

1. Change from backdoor pick-up to curb-side pick-up

2. Reduce normal crew size to two persons (one driver and one collector)
3. Eliminate the satellite vehicles and provide one 25-cu. yd., rear-load packer truck per crew
4. Institute a rational (i.e. even and fair division of work) task incentive program
5. Change collection methodology to one side collected at a time, two passes per street.

These changes represent Alternative IV (see Figure V-4). This recommendation is made for the following reasons:

1. The system changes have the potential of providing a high level of collection cost savings. Even though the cost comparisons indicate that Alternative V could provide a slightly greater cost savings (4%), the analysis performed here was not extensive enough to guarantee the significance of this difference.

2. Alternative IV will allow for the use of the same type of equipment that is currently owned by the MDS (rear load, packer trucks). Benefits from this will be that the system changes can be instituted sooner without the sale of still useable equipment and any currently possessed maintainance and replacement parts will still be usable. Also the MDS maintainance personnel are experienced with the currently used equipment type. Some time and expense is usually involved in selecting a new equipment type (as would be required with Alternative V).

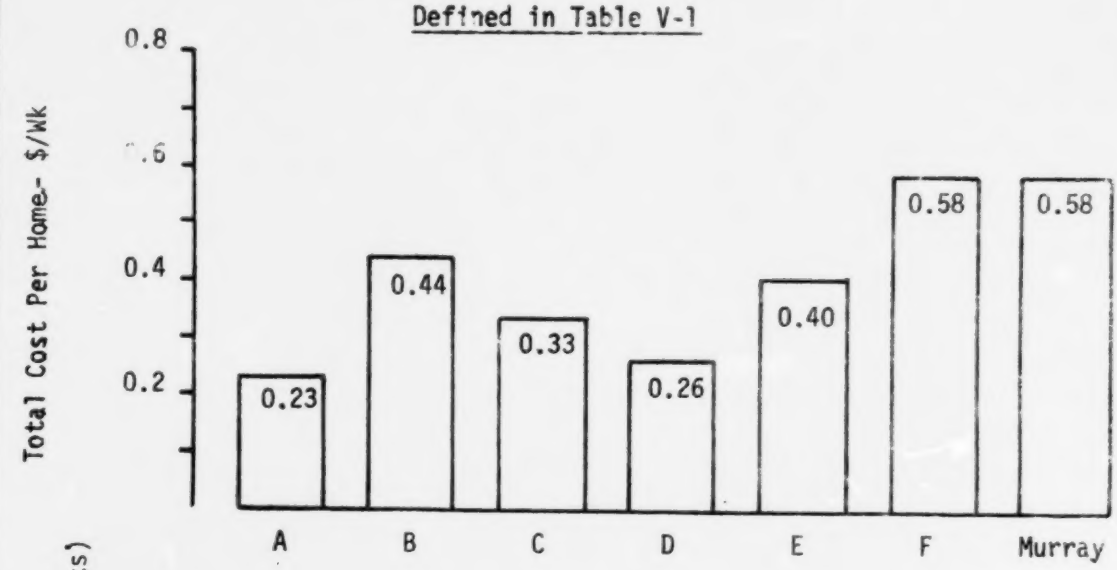
3. The number of collection personnel will not have to be reduced as drastically with Alternative IV as it would be with Alternative V. This will allow for system change implementation at an earlier date and also provide two more jobs to the Murray working public than Alternative V.

An operating cost estimate and discussion of the impact of the preferred residential solid waste collection system are included in Chapter VI.

FIGURE V-1

Comparison of Cost Factors for Systems

Defined in Table V-1



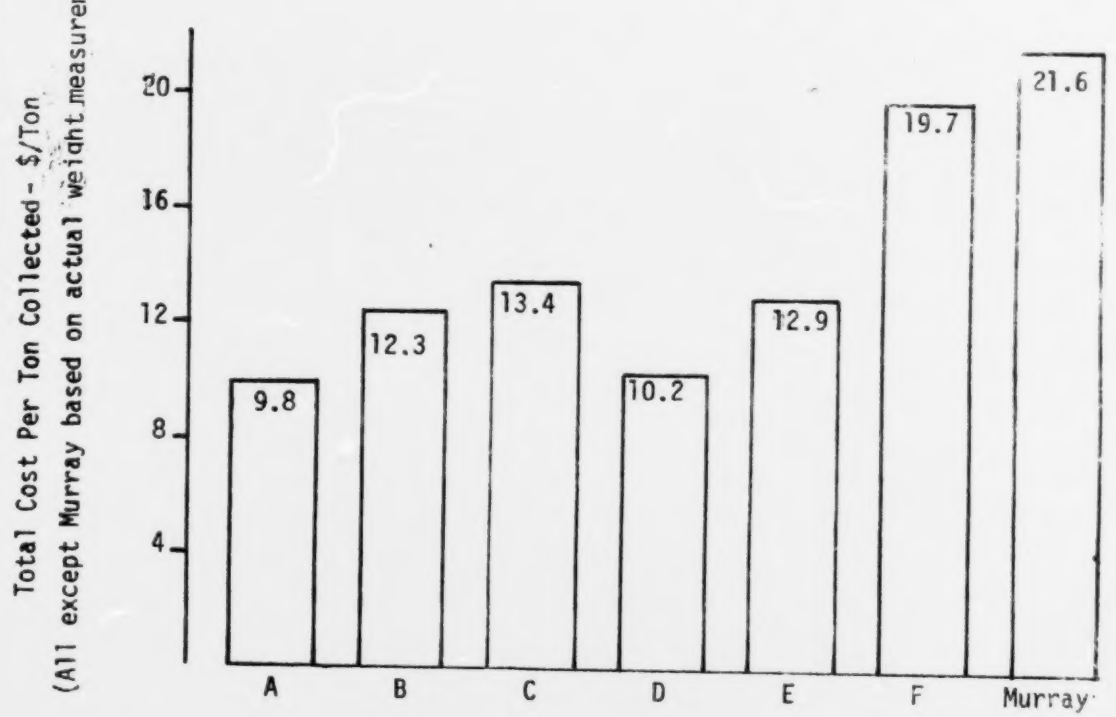
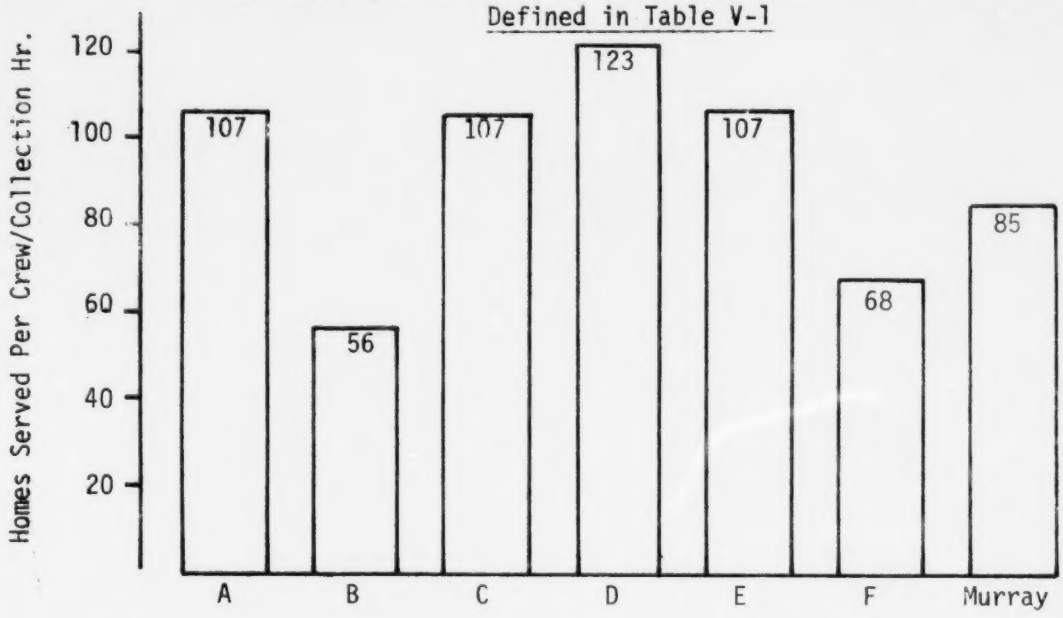


FIGURE V-2

Comparison of Per Crew Productivity Factors for Systems Defined in Table V-1



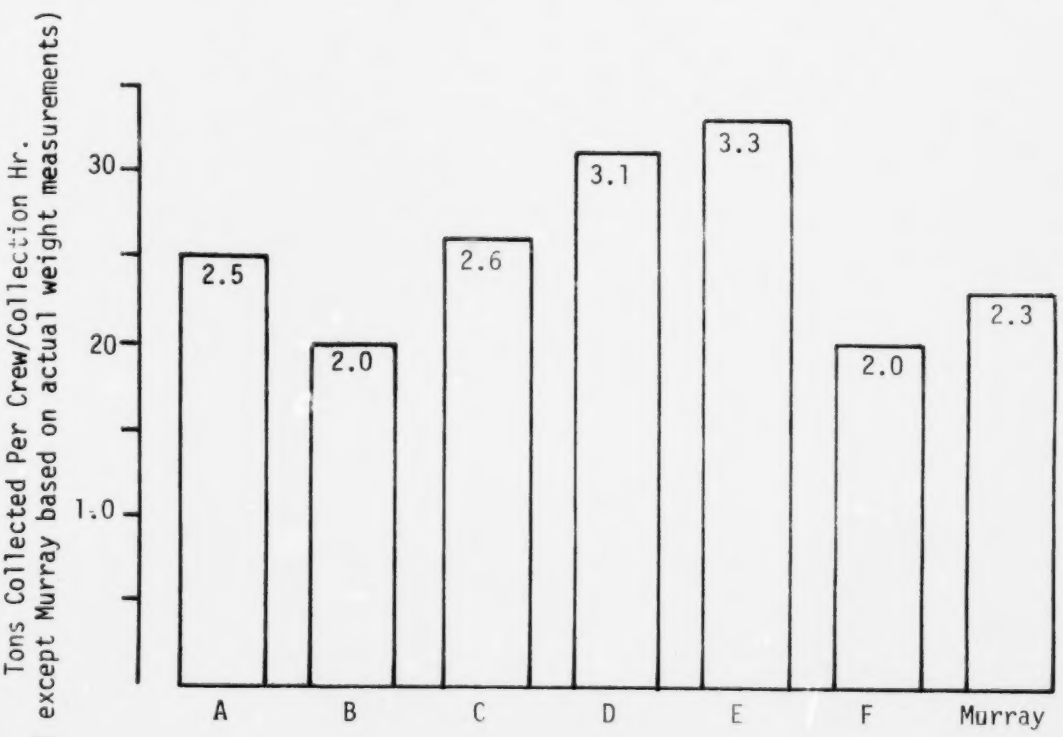
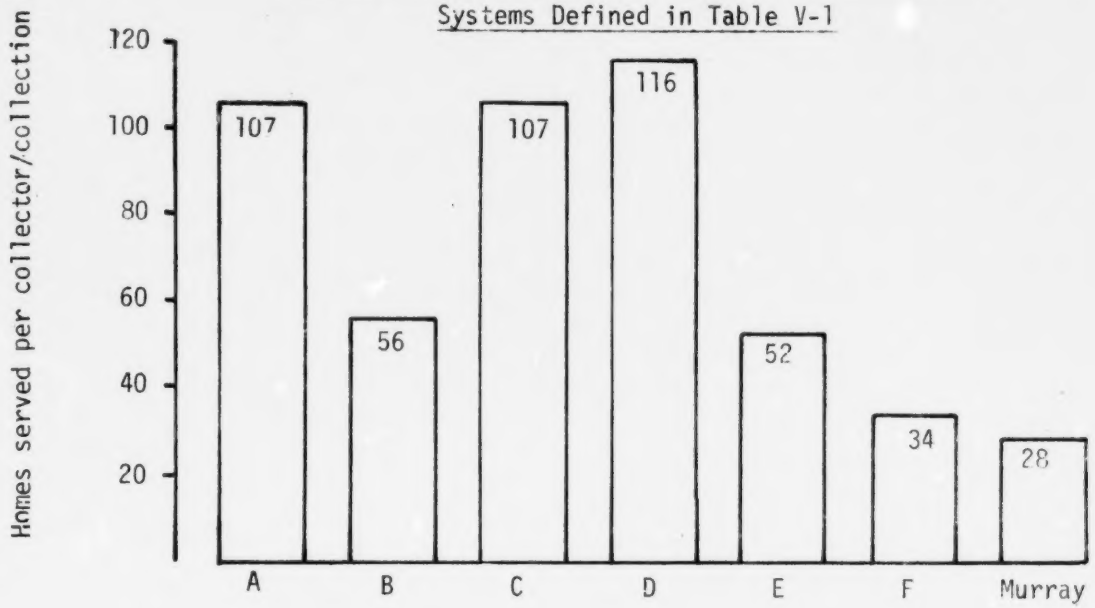


FIGURE V-3

Comparison of Per Collector Productivity Factors for Systems Defined in Table V-1



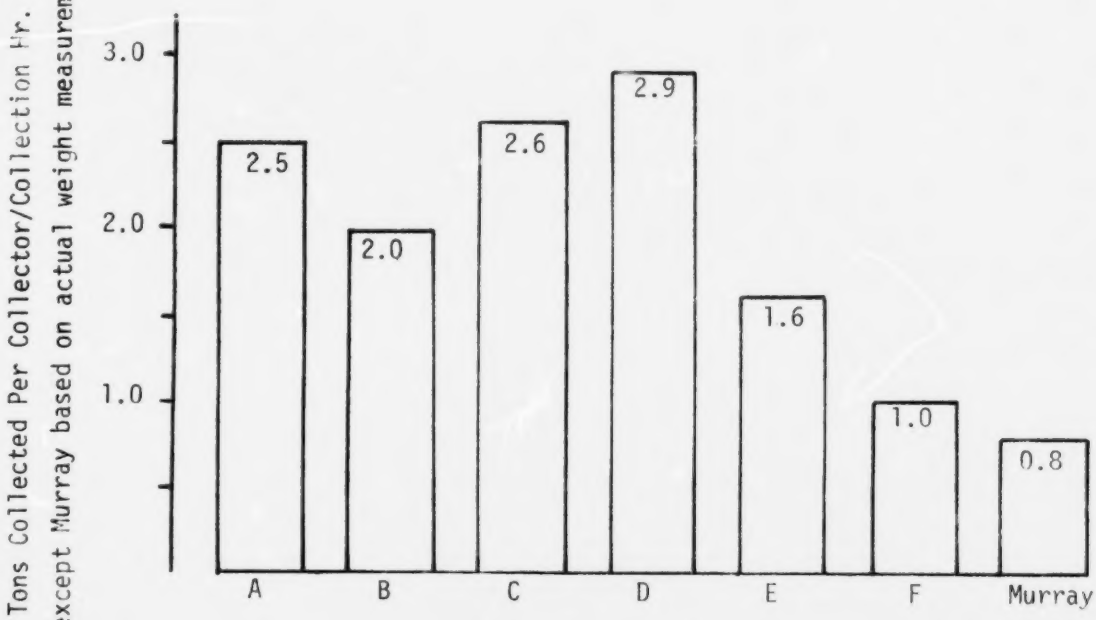
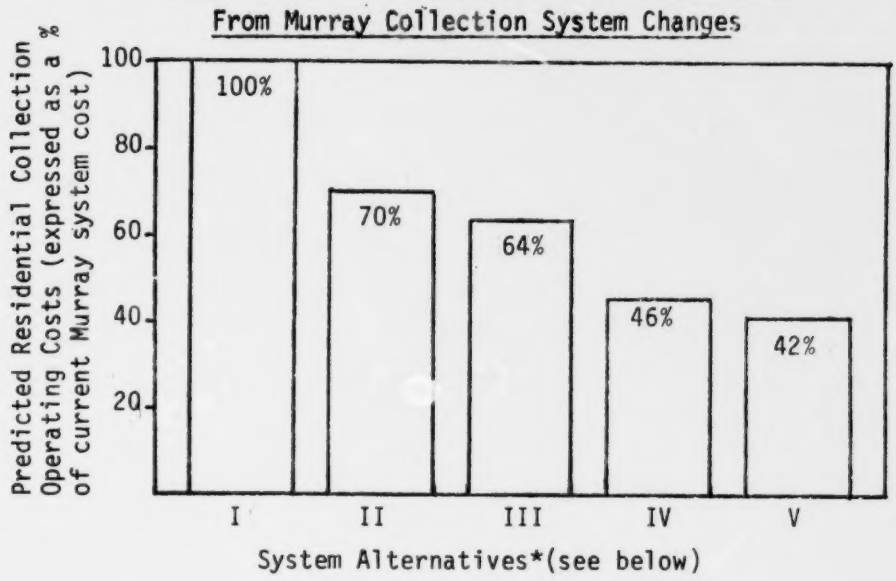


Figure V-4 Predicted Maximum Cost Reductions From Murray Collection System Changes



I No change from present operations.

II Change to curb-side collection; no change in equipment, crews, or incentive system.

III Change to curb-side collection; reduce crew size to 3; reduce equipment to one 25-cu. yd. rear load packer; institute well balanced task incentive program; collect two sides of street at a time.

IV Change to curb-side collection; reduce crew size to 2; reduce equipment to one 25-cu. yd. rear load packer; institute well balanced task incentive program; collect one side of street at a time.

V Change to curb-side collection; reduce crew size to 1; reduce equipment to one 25-cu. yd. side load packer; institute well balanced task incentive program; collect one side of street at a time.

* All alternatives assume elimination of idle personnel and equipment as necessary and a reasonably high level of personnel competency and work effort.

CHAPTER VI

IMPACT OF PREFERRED RESIDENTIAL SOLID WASTE COLLECTION SYSTEM

In the previous chapter, a preferred residential solid waste collection system was defined (henceforth referred to as the "preferred system"). It was estimated that implementation of the preferred system by the MDS would result in substantial reductions in residential collection costs. The objective of this chapter is to discuss the impact of adoption of the preferred system.

Comparison of Existing and Preferred Systems

The operating characteristics of the current residential collection system are compared with those of the preferred system in Table VI-1. Implementation of the preferred system will involve reduction of the crew size to two persons and elimination of the currently used satellite vehicle. A change to the preferred system will also involve a change from back-door to curb-side collection and a change from one pass collection to two pass collection. Implementation of a rational task incentive program is also assumed.

Economic Comparison

The estimated daily operating costs for the existing system and the preferred system are also given in Table IV-1. In Chaper V, it was estimated that a maximum of 54% of the residential collection costs could be saved by implementation of the preferred system. This estimate was based on comparison with an operating system (Comparison System C) which is designed similarly to the preferred system being discussed here. System C averaged 106 homes serviced per crew per collection hour during a one year study period. The existing Murray system serves approximately 85 homes per crew per collection hour. There are some secondary productivity affecting factors that were not considered for the purposes of this study. Some examples of these types of factors would be distance between served homes, street parking practices and weather. For the purposes here it will

TABLE VI-1

OPERATING CHARACTERISTICS OF EXISTING AND PREFERRED

RESIDENTIAL SOLID WASTE COLLECTION SYSTEMS

	Existing System	Preferred System
Frequency of Collection	1/Week	1/Week
Crew Size	4	2
Point of Pick-up	Back Door	Curb
Collection Methodology	Two sides of street, one pass	One side of street, two pass
Incentive System	None	Task
Type of Storage Container	Bags/Cans	Bags/Cans
Equipment	One 25-cu. yd. packer and one 1.6 cu. yd. satellite vehicle per crew	One 25-cu. yd. packer per crew
Homes served per crew per hour	85	85
Estimated Equipment Cost (per crew)	$111/Day	$95/Day
Estimated Labor Cost (per crew)	$174/Day	$93/Day*
Total (per crew)	$285/Day	$188/Day

*For preferred system, it is assumed that both crew members are paid at current driver rate ($4.40/hour).

be assumed that the MDS can maintain the current rate of collection with the preferred system (85 homes per crew per hour). It is believed that this is a conservative estimate. The result will be two crews collecting approximately the same number of hours per week as the existing system. Due to crew size and equipment reductions, it is estimated that the operating costs can be reduced from $285/day to $188/day (see Table VI-1) with implementation of the preferred system. This results in an estimated annual collection cost savings of approximately $50,000 (35%) to the MDS for two crews based on current equipment costs and pay scale. It is believed that this is a conservative and attainable estimate of potential collection cost savings.

There will be certain times and situations where it will be desirable to temporarily increase the crew size to three persons (one driver, two walkers). This change would probably be desirable under the following conditions:

1. It would be desirable from a safety aspect to have an experienced person work with each new worker for a training period.
2. During periods in the winter when snow and/or ice make working conditions hazardous for isolated periods of time.
3. In areas where many children are playing. This situation might occur during school holidays and near parks or other recreational areas.

It will be the task of the MDS management and personnel to identify the times and places where a third crew person will be beneficial to the safety of the crew and the general public. The economic impact of periodically operating with three members per crew would be to increase the daily operating costs to about $230/day per crew for the days when three people are required. This represents an estimated $55/day savings over the currently used system. If it is assumed that three-person crews would be required for a cumulative total of 3 months per year, the annual cost savings over the present system would be about $44,000 (31%).

Collection Routing

Implementation of the preferred residential collection system will require re-routing of the collection vehicles for two reasons.

1. Refuse will be collected from the curb-side. Regular daily routes must be established so the residential customers know when to place their garbage at the curb.
2. A two pass collection methodology will be used. The current routes are designed for one pass collection.

Macro-routing was used to divide the City of Murray into eight full day collection routes and two half-day collection routes. This will allow for two crews to accomplish weekly residential refuse collection in 4.5 days. Information about the routes is given in Table VI-2. The estimated number of homes served on each route is given along with the approximate collection time required to complete each route. These routes should be divided between the two crews, such that each crew spends approximately the same amount of time collecting each week.

Maps for each of the routes are given in Appendix D. The heuristic method of micro-routing was used to plan the collection vehicle paths for each of the routes (indicated by arrows on the maps in Appendix D). These paths allow for collection of all the residences on each route with a two-pass methodology. Dead travel and back-tracking were minimized. The micro-routes are all continuous and show no breaks for off-route lunch or rest periods. The preferred system includes a task incentive program and it will probably be desirable to the collection personnel to carry their lunches and stop on-route to eat. This will also be advantageous to the MDS. If the collection vehicle does leave the route at times, collection should be resumed at the point where it was discontinued.

Implementation of the Preferred System

The following general steps will be required to implement the preferred residential collection system. The preferred system can

TABLE VI-2

PREFERRED SYSTEM ROUTE INFORMATION

Route Code[1]	Estimated Number of Homes on Route	Estimated Collection Time Required[2]
A	481	5.7 Hours
B	464	5.5
C	498	5.9
D	484	5.7
E	237	2.8
F	476	5.6
G	254	3.0
H	490	5.8
I	451	5.3
J	464	5.5

(1) Routes E and G designed for one-half day collection. All other designed for full-day collection. Route maps are given in Appendix D.

(2) Based on rate of 85 homes serviced per crew per hour.

be started with the present equipment (one 25-cu. yd. packer and one 18-cu. yd. packer); however, due to the fact that the smaller truck will still have to make two landfill trips per day, maximum efficiency will not be attained until this piece of equipment is replaced by a 25-cu. yd. vehicle.

1. Time should be devoted to reviewing the preferred system operational plan. The MDS management and collection personnel should try to anticipate any problems and adjust for them.
2. The collection crews should spend some time (one week) collecting with the present system using the new routes (see Appendix D). Since the present system is the type that is most efficient with a one pass route (the micro-routes in Appendix D are designed for two pass), this will probably require some extra working hours. It is believed that the time will be worthwhile in helping the collection personnel learn the new routes and minimize missed stops during preferred system start-up.
3. A city ordinance should be passed that will require curb-side placement of domestic refuse (to become effective at a specified future date). Special provisions should be made for people who are physically unable to comply (the elderly and handicapped).
4. Notification to the public that curb-side placement of refuse will be required along with the effective date.
5. Notify each home owner of which week-day he/she should place refuse containers at the curb (could combine notification required in steps 4 and 5 into one letter or pamphlet).
6. On the date when curb-side placement becomes effective, start collections as described by the preferred system.
7. Adjust as needed for any unforeseen isolated problem areas.

It should be kept in mind that during the start-up period, there will most likely be some problems (collections taking longer than anticipated, missed stops, etc.). It is believed that these problems will be overcome as the MDS personnel and the public become acquainted with the new system.

CHAPTER VII

COMMERCIAL SOLID WASTE COLLECTION

The objectives of this chapter are to present information on the existing commercial solid waste collection system in Murray and discuss some potential upgrading techniques.

Existing Commercial Solid Waste Collection System

Currently commercial solid waste collection is performed by two crews. One crew works during the day (beginning work at 7:00 a.m.) and the other works during the night (beginning work at 4:30 or 5:00 p.m.). Both crews use the same 25-cu. yd. rear loaded packer vehicle. Each crew is made up of two persons.

At present, three types of commercial solid waste containers are used in Murray.

1. Bins - 2-cu. yd. metal bins with hinged lids and casters. Dumped with the aid of a chain wench.
2. Box Sheds - stationary sheds where discarded corrugated boxes are stored for pick up. Emptied by hand.
3. Cans - covered metal refuse cans (20 to 32-gallon). Dumped by hand.

The numbers of these types of containers collected by each crew during the week are given in Table VII-1. It can be seen that the east crew (day) collects the majority of the cans, while the west crew (night) collects most of the bins and box sheds.

Commercial customers in Murray are charged for refuse collection based on the number and type of containers that they use and the frequency with which they are collected. Table VII-2 presents the number of commercial customers, the number of containers that they use and the frequency with which collection is made (bin and box shed customers only). The majority of the bin customers (84%) have only one bin and most of those require collection only once per week (56% of one bin customers; 47% of all bin customers).

TABLE VII-1

NUMBER AND TYPE OF CONTAINERS COLLECTED BY

MURRAY COMMERCIAL CREWS[1]

	East Crew[2]			West Crew[2]		
Day of Week	Bins	Box Sheds	Cans	Bins	Box Sheds	Cans
Monday	59	5	152	83	10	78
Tuesday	50	2	180	51	2	86
Wednesday	50	5	177	65	7	133
Thursday	45	2	146	70	3	100
Friday	45	5	127	70	9	50
Saturday	--	--	--	66	3	18
WEEKLY TOTAL	249	19	782	405	34	465

(1) Based on count by MDS personnel.

(2) Bins - 2 cu. yd. covered metal bins.

Box Sheds - stationary sheds where discarded corrugated boxes are stored for pick up.

Cans - 20 to 32-gallon covered metal or plastic cans.

TABLE VII-2

NUMBER OF COMMERCIAL SOLID WASTE COLLECTION CUSTOMERS BY NUMBER OF CONTAINERS AND COLLECTION FREQUENCY*

	Pick-ups Per Week					
Number 2 Cu. Yd. Bins	1	2	3	4	5	6
1	80	30	13	6	2	13
2	4	1	4	0	0	9
3	0	1	1	2	1	1
4	0	0	1	0	1	0
8	0	0	0	0	0	2
Number Box Sheds						
1	2	0	0	0	6	4

*Based on May 1979 billing list.

At this time, virtually no data on the quantities of commercial solid waste collected in Murray (weight basis) is available. As with domestic solid waste production rates, the rate of commercial waste production varies from community to community. For the purposes of estimating the quantity of commercial refuse collected in Murray, the production rate of 0.8 lb./person-day will be used (seven-day per week basis). This figure is consistent with measurements taken for the southeastern United States.[6] It is thus estimated that approximately 42 tons of commercial waste is collected in Murray per week. This figure is based on the entire city's population (currently estimated to be 15,100; see Appendix A). This includes the on-campus residents at Murray State University which are not served by MDS residential collections (about 2,800). It is assumed that their commercial activities are, for the most part, with off-campus business establishments.

Commercial Solid Waste Collection System Upgrading Techniques

The MDS management has expressed the following concerns about the current commercial solid waste collection program:

- The rear loaded bin system currently used is not satisfactory from a collector safety point of view.
- The box sheds currently used are, for the most part, unsightly and a source of litter. It is also believed that since these sheds must be emptied by hand, they are also a potential source of worker injury.
- The MDS management realizes that the 2-cu. yd. rear-load bins currently used are under sized for many of the commercial locations in town. The result is that many commercial customers have to use multiple containers and have them emptied more times per week than would otherwise be required (for health reasons, etc.). It is felt that this situation results in a low level of collector productivity.

In the following sub-sections,two methods of commercial solid waste collections will be discussed for upgrading of the Murray system.

Front Loaded Containers

The MDS management has expressed an interest in using large front load type bins for a portion of their commercial collection activities. These bins commonly range in capacity from 2 to 10 cu. yd. and require a special collection vehicle.

Table VII-3 presents the total number of rear load bins currently in use in Murray, along with the number and sizes of front load bins required to replace them. It should be noted that the front load bin estimate is based on the once per week volume required to replace the weekly collected volume of the rear load bins. It has been estimated that approximately 10% of the commercial customers in Murray require refuse collection more than once per week for health hazard reasons (food wastes, etc.). This fraction has not been accounted for in Table VII-3. It can be seen from Table VII-3 that the estimated annual container cost for the two containerization alternatives are approximately equal ($16,000/year each). Commercial refuse bin costs are currently borne directly by the customers (they have to buy their own bins).

If a front load bin commercial collection system was initiated in Murray, the crews and equipment could be divided in the following way:

- One two-person crew using a 25-cu. yd. rear load vehicle to pick up cans.
- One two-person crew using a 25-cu. yd. front load vehicle to pick up front load bins (these bins replacing the currently used rear load bins and box sheds).

Assuming this type of arrangement, an annual cost estimate for the commercial collection system was made. The details of this cost estimate are given in Appendix E. Table VII-4 presents the estimated annual costs for the present commercial collection system as well as those for the system using a combination of front load bin and can containerization. Though the predicted annual costs for the alternate system are a little higher ($114,000/year) than the existing system ($109,000/year) for the level of estimate made here, these costs can be

TABLE VII-3

REAR LOAD BINS CURRENTLY USED AND

FRONT LOAD BINS REQUIRED TO REPLACE THEM

Rear Load, 2 Cu. Yd. Bins Currently Used

Approximate Number = 222

Initial Cost[1] = $280 each

Annualized Cost[2] = $72/year each

Total Annual Cost[3] = $16,000/year (all containers)

Front Load Containers Required to Replace Currently Used Bins[4]

Size[5]	Number[5]	Initial Cost Each[6] ($)	Annualized Cost Each[6] ($/yr.)
2 cu. yd.	91	244	38
4 cu. yd.	53	371	58
6 cu. yd.	14	483	75
8 cu. yd.	97	569	89

Total Annual Cost = $16,000/year

(1) Information provided by MDS Management.

(2) Based on expected life of five years (MDS Management) and 9% minimum rate of return.

(3) These costs currently borne directly by the customers; i.e., they have to buy their own bins.

(4) Assuming once per week pick up. Does not account for approximately 10% that require pick up more than once per week.

(5) Estimate of most economical distribution.

(6) See Appendix E.

TABLE VII-4

COST COMPARISON FOR COMMERCIAL COLLECTION ALTERNATIVES

	Equipment	Crew	Costs(1) Containers ($/yr.)	Equipment ($/yr.)	Labor ($/yr.)	Total ($/yr.)
Current System	2, 25 cu. yd. rear loaded packers(2)	Two crews with two persons each	16,000	44,600	48,600	109,000
Front Loader System	1, 25 cu. yd. rear load packer	Two persons				
	1, 25 cu. yd. front load packer	Two persons	16,000	49,800	48,600	114,000

(1) See Appendixes B and E for cost estimates.

(2) Actually, the same truck is used at different times of the day for both routes. For economic purposes, it is assumed that the packer will last only half as long as a packer used for one route and thus is economically equivalent to two vehicles.

assumed equivalent. In reality, it is highly possible that front load collection will require less working hours than collection of an equivalent amount of waste with the presently used rear load bin/box shed system (a full 40-hour week was assumed for both systems for the cost estimate). This could mean that the labor costs predicted for the alternate system are higher than those that would actually be incurred.

It is concluded, based on the information presented here, that the commercial system can be upgraded with front load bin collection at an annual cost which is equivalent to or less than the annual cost for the current system.

Roll-Off Containers

Another method of commercial refuse collection that the MDS management has expressed an interest in is roll-off type containers. These containers typically have capacities of 20 to 60 cu. yd. and come with and without self-contained compaction units. The containers are left at the customer's place of business where they are filled with refuse. The collection vehicle which picks up the containers consists of a heavy-duty truck chassis with a special hoist mounted on it. One container at a time is hoisted onto the vehicle, carried to the disposal facility, emptied and then returned to the customer.

With the aid of MDS personnel, it was predicted that roll-off containers could be used at several locations in Murray. To justify the use of these large containers, they must be placed at points of high refuse production. Sites that have this potential and are currently served by the MDS include several large businesses, several shopping centers, the hospital, and a few schools. It is possible that if roll-off container collection was available several new customers who are currently served by other means (private haulers, etc.) could be served by the MDS. These include a large manufacturing plant, the university and construction companies.

Based on information provided by vendors, a cost estimate for roll-off container equipment was made. The details of this estimate are given in Appendix E. The estimated annual costs for the collection vehicle (hoist and chassis) and operating crew (two persons) are about $48,000/year. The container costs for roll-off containers are significantly less than for the 2-cu. yd. rear load containers now being used on a per volume capacity basis. They range from $12, to $21 per cu. yd. per year (depending on size), while the 2-cu. yd. rear load containers cost about $36 per cu. yd. per year.

Since roll-off containers require a large point source of solid waste and demand a relatively large storage area (as compared to other types of refuse containers), they are not usable for all commercial locations. With the aid of MDS personnel, it has been estimated that the potential market for roll-off refuse containers is equivalent to about one-third of the total container volume of all the 2-cu. yd. rear load bins currently used. It is not known at this time how many man-hours per week would be required to provide the roll-off container service. Based on the predicted market and the estimated equipment and labor costs for the roll-off service, the annual cost for the roll-off container service would range from $180 to $340 per cu. yd. container volume per year (the lower figure assuming no labor cost at all and the higher figure assuming 40 hours per week). If the market for roll-off containers could somehow be increased to 50%, this range would drop to $120 to $230 per cu. yd. container volume per year. Assuming that one of the present crews could make all bin collections (i.e., one crew working at collecting from bins for 40 hours per week), the costs for the current system are in the range of $100 to $110 per cu. yd. container volume per year. This cost is lower than even the lowest cost predicted for roll-off container service. The reason for this is the under-utilization of the collection vehicle (hoist truck). For a roll-off container system which fully utilizes its equipment, the per unit collection costs would be lower than for a small container, rear load system.

Based on the information presented here, it is concluded that roll-off container type refuse collection is not economically practical for the City of Murray at this time, unless a significantly larger market for the service can be developed.

CHAPTER VIII

MATERIALS RECOVERY

The objective of this chapter is to make a preliminary assessment of the feasibility of a materials recovery program to be conducted in conjunction with the solid waste collection system in Murray. The following sections of this chapter will discuss materials separation techniques and a preliminary market survey.

Materials Separation and Gathering Alternatives

In general, there are two basic methods currently in common use for reclaimable materials separation and gathering:

1. Centralized materials separation facilities.
2. Source separation by solid waste producers.

The centralized materials separation alternative involves hauling of the mixed solid waste stream to a central facility. Here the solid waste is manually or mechanically separated. Salable fractions of the waste are stored for shipment to buyers and the non-salable fraction is hauled to the refuse disposal facility. Manual materials separation on a large scale is generally quite expensive and involves health hazards for working personnel. The mechanical methods currently in use for materials separation include magnetic separation (recovery of ferrous metals), air classification (separates waste into components by density) and froth flotation (separation of floatable materials). Materials separation facilities will commonly use one or more of these technologies preceded by a refuse shreading device.

Centralized mechanical materials separation facilities are usually quite expensive to install. Based on information reported for 20 facilities that were operating, under construction, or being planned in 1978, the average required capital investment was approximately $24,000/TPD capacity (range 5,000-78,000).[8] These facilities range in capacity from 150 to 3,000 TPD. Based on an estimated combined commercial/residential refuse production rate of about 32 TPD for the City of

Murray (five-day basis) and the average capital cost of $24,000/TPD capacity, it is estimated that a centralized mechanical materials separation facility for the city would require a minimum of $750,000 in initial capital expenditure. In reality, due to economics of scale, the facility could cost considerably more. It is believed that an expenditure of this magnitude would not be economically justified for materials separation at the small scale being considered here.

A method of reclaimable materials separation from solid waste that has been successfully used for small scale applications is source separation. The idea here is to motivate the refuse producer to separate the waste into its fractions as it is being thrown away. An example would be for a home owner to have one plastic bag for aluminum cans, one for discarded glass containers and one for all other refuse. On collection day, these separated wastes are picked up and placed in different compartments of the refuse collection vehicle. The non-saleable refuse is disposed of and the saleable materials are stored at a central location for shipment to buyers.

Source separation programs are generally relatively inexpensive to operate but require a high level of public support and participation. Some techniques that have been used to motivate people to participate are listed below:

- Informing the public that the revenues derived from the materials recovery program will be used to help control solid waste collection costs and thus minimize rate increases.
- Use of the money generated for highly visible civic improvements (public park improvements, etc.).
- Providing the home owners with color-coded refuse bags for the different materials to be separated. This makes source separation more convenient for the public and the collectors.

- Radio, television, and newspaper advertisements promoting the reclaimation project.
- Passing of city ordinances that require people to separate their refuse.

The combinations of techniques that have promoted successful separation programs vary from application to application. Before instituting a source separation program, a careful study of incentive techniques that have been used in other communities should be made. A source separation program for Murray should be planned based on the findings of this study and an assessment of pertinent physical parameters and public attitudes.

Past experience has shown that it usually takes continued effort over a relatively long period of time to attain a high level of public participation in a source separation program. Figure VIII-1 shows the level of public participation in a newspaper recycling program over a period of time. In this example it required about four years to reach a point where 80% of the public was involved in the program. The important thing to note here is that when planning a source separation program, the organizers must be prepared to maintain their efforts over an extended period of time even though initial public support may be low and discouraging.

It is believed that of the two materials separation techniques discussed here the most practical approach to materials recovery for the City of Murray is source separation.

Preliminary Market Survey

Estimated Quantities of Recyclable Materials

It has been estimated here that about 158 tons of combined commercial and residential solid waste is collected in Murray each week. Table VIII-1 gives an estimate of the 1976 solid waste stream composition (national average). Also given is an estimate of the amount of these materials collected in Murray (ton/week). These figures

TABLE VIII-1

ESTIMATED QUANTITIES OF RECYCLABLE MATERIALS IN MURRAY SOLID WASTE

Material	Portion of Solid Waste Stream[1] (%)	Estimated Amount Collected in Murray[2] (Ton/Week)
Paper (Total)	32	50
Newspaper	6	9
Corrugated	8	13
Office Paper	3	5
Other Paper	15	24
Glass Containers	9	14
Ferrous Cans	4	6
Aluminum Cans	1	2
Other	54	35

(1) From "Refuse Report", International City Management Association, July-September, 1978, Vol. 4, No. 3.

(2) Based on an estimated 158 ton/week commercial and residential refuse collected in Murray.

represent an estimate of the maximum amount of the materials that can be recovered. The quantities actually recovered would be strictly dependent upon the success of the source separation program (the program depicted in Figure VIII-1 attained 80% newspaper recovery).

The following sub-sections present information obtained from potential buyers of reclaimed materials.

Paper

Two different types of potential buyers for reclaimed paper were contacted. One type was a firm which is in the business of buying and selling waste paper (stock dealer), and the other type consisted of paper mills which buy the waste paper for their own use (recycler).

The stock dealer contacted (Consolidated Fibers, Cincinnati) indicated a willingness to buy reclaimed paper from Murray. The dealer would pick-up the paper at Murray in 20 to 40 ton lots and would require that the paper be baled. To receive the optimum price for the paper, it would have to be segregated into newspaper (no magazines), corrugated and mixed (magazines, office, etc.) classifications. The current prices (August 1979) being paid for these types of paper are newspapers, $30/ton; corrugated, $55 to $60/ton; mixed, $20 to $22/ton. If any mixing of paper types occurs (i.e., a bale of newspaper with a few magazines included), the mixed paper price would be paid. The waste paper market is highly variable and the dealer suggested that when planning a recovery program the organizers should be prepared for occasional minimum prices of $25/ton for corrugated, $0 to $20/ton for newspaper, and no market at all for mixed paper.

Three paper producers or recyclers were contacted. One of these firms (Kimberly Clark, Memphis) buys through a central purchasing office (Chicago). At present they are only buying scraps from one paper cup manufacturer in multiple rail car load lots. Another firm (Alton Boxboard, Memphis) expressed an interest in buying reclaimed

paper, but stated that large quantities would be required (40 tons/shipment) and the paper would have to be baled. They also mentioned special packaging requirements for newspaper. The third company contacted (Container Corporation of America, Chattanooga) buys waste paper regularly at their plant (they provide no shipping). The prices currently being paid are given in Table VIII-2. Also included is the haul distance and the "break-even" distance. The break-even distance is the maximum distance that the paper can be hauled before hauling costs exceed the price paid for the shipment (does not account for other costs associated with collecting and storing the paper). It can be seen that the only type of paper which might be economically transported to this buyer is computer cards.

To summarize, at present, the City of Murray would have to consider the following requirements before getting involved in the waste paper reclaiming business on an economical basis:

1. Provide a fairly substantial amount of dry storage area (at least 3,000 cu. ft.) in which to accumulate paper for intermittent pick-up.
2. Acquire and operate a small, hand-fed baler. A covered, preferably indoor, working area adequate to set up and operate this baler would be required.
3. The paper would have to be separated to assure a continuing market.

Glass

Three buyers of reclaimed glass were contacted. All three are in the business of glass container production (Chattanooga Glass Co., Chattanooga, Tennessee; Thatcher Glass Co., Lawrenceburg, Indiana; Pierce Glass Co., Lincoln, Illinois). The reclaimed glass buying policies of all these were essentially the same:

1. Only container glass will be purchased (jars and bottles).
2. Glass must be clean (free of caps and labels).
3. Glass must be separated by colors.
4. Glass must be delivered to the plant.

TABLE VIII-2

WASTE PAPER SELLING PRICE SUMMARY[1]

Paper Type	August 1979 Price ($/Ton)	Road Distance to Buyer[2] (Mi)	Break-Even Distance[3] (Mi)
Mixed	17	260	170
Newspaper	20	260	200
Corrugated	25	260	250
Computer Punch Cards	40	260	400

(1) Information for sales to Container Corporation of America (price paid for paper delivered to Chattanooga). August 1979.

(2) Approximate driving distance Murray, Kentucky to Chattanooga, Tennessee.

(3) Maximum economic haul distance assuming $0.10/ton-mile. Further distance requires more haul cost than price paid for paper.

Table VIII-3 summarizes the price information obtained from these buyers. Also given are the road distances from Murray to the buyers and break-even distances. It can be seen that for only one of the three buyers would the haul costs be less than the price received for the glass (the Lincoln, Illinois buyer). It is doubtful that this small revenue margin ($1.60/ton) would compensate for the costs incurred in collecting, cleaning and sorting the glass.

Unless other markets can be defined, it is doubtful that the City of Murray can reclaim glass on an economical basis at the present time.

Ferrous Metal

Several steel mills were contacted. All of these mills are in the business of producing steel, at least partially, from scrap ferrous metals. In all cases the mills buy only large quantities (minimum of 50 tons) of shreded and graded scrap metal. They deal with large scrap dealers who have the facilities to shread and grade scrap that they buy from smaller dealers or individuals.

Based on the suggestion of a steel mill representative (Tennessee Forging Steel Corp., Harriman, Tennessee), a large scrap dealer in Nashville was contacted (Stiner-Liff Iron and Metal). The person spoken with here stated that they are currently buying miscellaneous steel for $30/ton, automobile steel for $40-$43/ton, galvanized steel for $20/ton, and old appliances for $30/ton. These prices are for scrap delivered to Nashville. He said that the scrap must be fairly clean (free of upholstery, etc.). This firm does not currently buy the type of ferrous scrap that is found in large quantities in municipal refuse (cans, etc.).

Aluminum

Three types of potential scrap aluminum buyers in the Kentucky-Tennessee area were contacted; primary aluminum producers, secondary aluminum smelters, and large aluminum companies with recycling divisions.

TABLE VIII-3

BUYERS OF RECOVERED GLASS[1]

Location	Current Price Paid ($/Ton)[2]	Approximate Road Distance from Murray (Mi)	Break-Even Distance[3] (Mi)
Chattanooga, Tn.	20	261	200
Lawrenceburg, Ind.	30	305	300
Lincoln, Ill.	30	284	300

(1) All buyers require:
a. Container glass only (no window glass, mirrors, etc.).
b. Glass clean and free of labels and caps.
c. Glass sorted by colors.

(2) August 1979. Price for glass delivered to buyer.

(3) Distance where haul cost is equivalent to price paid for glass. $0.10/ton per mile assumed haul cost.

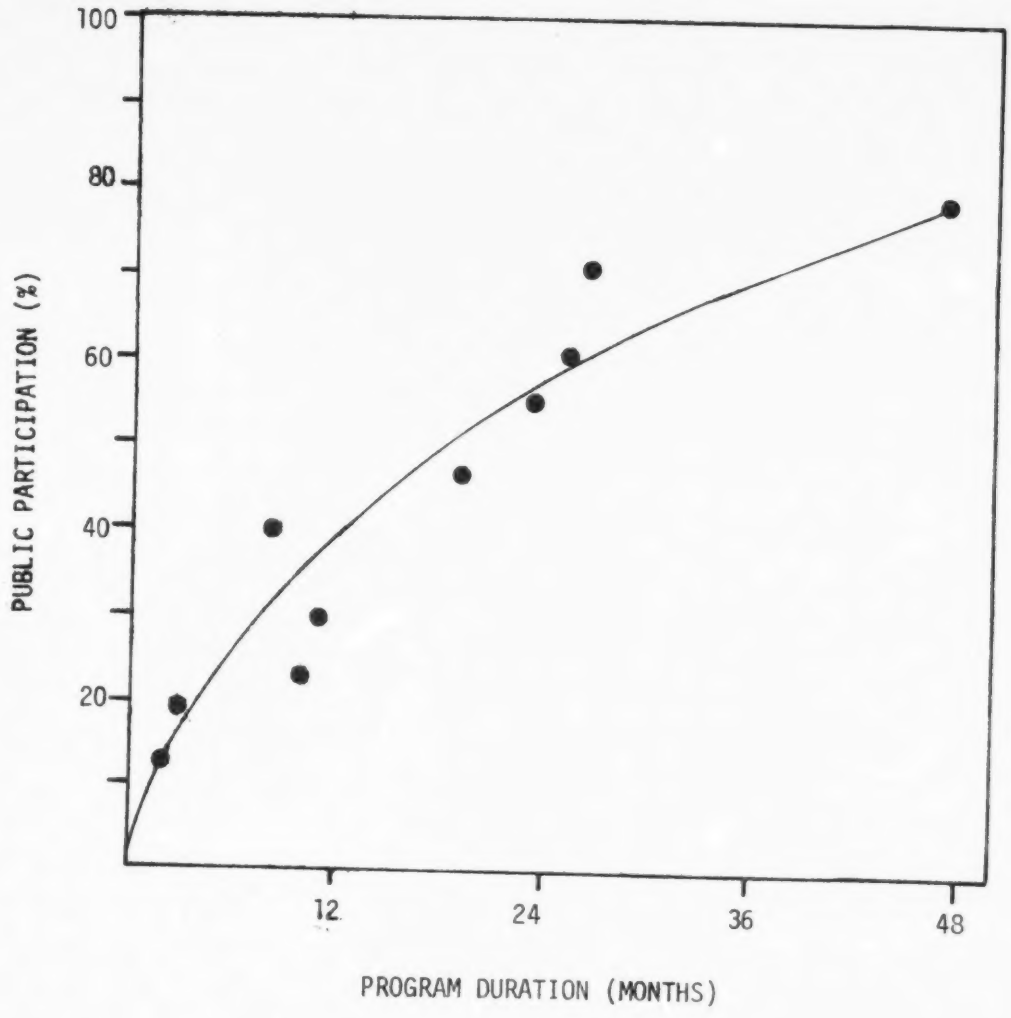
Of the two primary producers in the area, neither one uses scrap aluminum. The two secondary smelters primarily buy alloy grades that are not found in great quantities in municipal refuse (structural aluminum, etc.). One of the two secondary smelters (Excel Smelting Corp., Memphis, Tennessee) will buy aluminum cans but are currently paying a relatively low price ($400/ton) and would require that the cans be shipped to Memphis.

The Alcoa Aluminum Company is one of the larger aluminum companies which buys the type of aluminum which could be obtained from a municipal recovery program. At this time, they do not have any recycling centers in the area in question and would require that the scrap be baled and transported to their nearest plant. They currently pay $600 to $640/ton for scrap aluminum cans.

The Reynolds Aluminum Recycling Company has a recycling center in Louisville, Kentucky. The person contacted here expressed a high level of interest in participating in a materials recovery program with the City of Murray. They would be willing to send a truck to Murray to pick-up loads of scrap aluminum in 5,000 lb. lots (primarily cans). If the recovery program in Murray was able to compile significant amounts of scrap on a consistent basis, a regular pick up could be arranged (once per month, once every three months, etc.). If not, the recovered aluminum would be picked up as needed. This flexibility is especially attractive during the start-up period of the materials recovery program when public participation is low and quantities of aluminum that will be available at any given time are uncertain. The scrap would not have to be baled, but should be boxed or bagged. The price paid for aluminum by this firm varies depending on how far they have to haul it and market price; but, currently, they are guaranteeing a minimum of $460/ton. The aluminum is taken to the recycling center where it is shreded and separated from any other debris. Payment is made on the actual amount of aluminum in the shipment after separation.

FIGURE VIII-1

PUBLIC PARTICIPATION IN A NEWSPAPER RECYCLING PROGRAM*



*Taken from Vesilind and Warner.[7]

CHAPTER IX

REFUSE TRANSFER AND LARGE SCALE BALING

The objective of this chapter is to discuss the feasibility of solid waste transfer and transfer/baling operations for the city of Murray.

Solid Waste Transfer

Solid waste transfer facilities are often used to reduce the costs of hauling refuse. Refuse collection vehicles transport the solid waste to a central facility where it is unloaded either directly or indirectly onto a transfer vehicle that will carry it to the ultimate disposal site (landfill, incinerator, etc.). Transfer vehicles can transport solid waste at a lower cost than refuse collection vehicles. A solid waste transfer operation becomes economically attractive when the costs of the transfer station plus the costs to transport the waste to the disposal site with a transfer vehicle are less than the costs to transport the refuse directly from the route with the collection vehicles.

It has been estimated that the MDS collects and disposes of approximately 32 tons of combined commercial and residential solid waste per day (5 day per week basis). This corresponds to approximately 8320 tons collected per year. Vesilind, Nissen, and McAlister [6] developed the following polynomial based on cost data from operating transfer facilities.

$$M = (3.44 \times 10^{-6}) N^3 + (8.6 \times 10^{-4}) N^2 - (7.29 \times 10^{-2})N + 2.73$$

where: M = transfer facility cost ($/ton)

N = transfer station capacity (1000 ton/year)

This empirical equation provides an estimate of transfer station capital and O & M costs as a function of station capacity. Applying the estimated solid waste production for Murray (8.32×10^3 ton/yr) to this equation yields an approximate cost of $2.2/ton for solid waste transfer.

The following national average haul costs were estimated by EPA in 1976[6].

Packer truck - $0.32/ton/mile

Transfer vehicle - $0.07/ton/mile

Based on these haul costs and the estimated transfer cost, Figure IX-1 was developed. The break even distance, in this case, is approximately 9 miles. This means that if the transfer station is located more than 9 miles

from the landfill then total refuse transport costs can be reduced by installing a transfer system. At any point closer to the landfill than 9 miles, hauling with a transfer system is more expensive than hauling refuse directly from route with collection vehicles. The Murray landfill is located 7.5 miles from the city limit and the 9 mile break even distance encompasses most of the city's area.

Based on the estimated relative economics of solid waste transfer versus hauling refuse with collection vehicles, it is believed that solid waste transfer in itself is not an economically feasible alternative for the city of Murray.

Large Scale Solid Waste Baling

Solid waste baling facilities are used for compacting large amounts of relatively loose refuse into denser, more easily handled bales. Typically, packer vehicles, such as the ones used by the MDS, will compact refuse to a density of 300 to 500 lb/cu. yd.[3] If dumped from the packer vehicle at the landfill the waste will assume an in-place density of about 800 lb/cu. yd. with the compaction provided by overburden pressure and landfill equipment.[2] Over long periods of time, through the action of continued pressure and biological decomposition, the refuse will attain an in place density of approximately 1000 lb/cu. yd..[3] Depending on the type of baler used, bales are formed that have densities of 1000 to 2000 lb/cu. yd.. At the present little is known of the long term volume reductions and density changes that occur to waste disposed of in balefills (landfills where bales are disposed of).[9]

Some advantages that occur as a result of using baling operations are as follows:

1. Since refuse volume is reduced when baled, the life of the landfill is greatly extended. It has been estimated that the useable life of a given landfill site can generally be doubled when baling of solid waste is practiced.
2. Bales are easier to handle than loose refuse.
3. Bales can be less expensive to transport than loose refuse if rail hauling is used.
4. Balers can be used to bale reclaimed materials separately for sale.

5. Balefills do not always require daily cover.

Some disadvantages of baling are listed below:

1. Baling facilities require substantial initial capital investment.
2. Baling prevents resource recovery once the bale is formed.
3. Due to road weight limitations, bales cannot be transported at a significantly lower cost than loose refuse (from packer vehicle) when trucks are used for hauling.
4. Currently there are some gaps in the knowledge of gas production and leachate formation in balefills.

In the case of Murray, Kentucky the distance to the landfill and existing facilities are not such that baling can be used to reduce refuse hauling costs (rail haul not feasible). Also it is very doubtful that a large baler could be justified solely for the purpose of baling reclaimed materials (see Chapter VIII for discussion of smaller balers for recovered material compacting).

An estimate was made of the cost of a solid waste baling facility that would be adequate for the baling of the solid waste collected in Murray. This cost estimate is detailed in Appendix F. According to this estimate the equivalent annual costs for the baling facility would be approximately $65,000/yr.

Appendix G gives the details of an estimate of the equivalent annual cost of present operation of the Murray landfill. These costs are estimated to be about $95,000/yr. If operated as a balefill certain cost savings could be incurred (lower equipment and labor costs and extended landfill life). Appendix G also contains an estimate of the costs of operating the Murray landfill facility as a balefill. It was estimated that, if disposing of bales rather than loose refuse, annual costs could be reduced to $68,000/yr. These cost estimates are summarized as follows:

Annual Cost of Landfill (as presently operated) = $95,000/yr

Annual Cost of Baling Facility = $65,000/yr.

Annual Cost of Balefill = $68,000/yr.

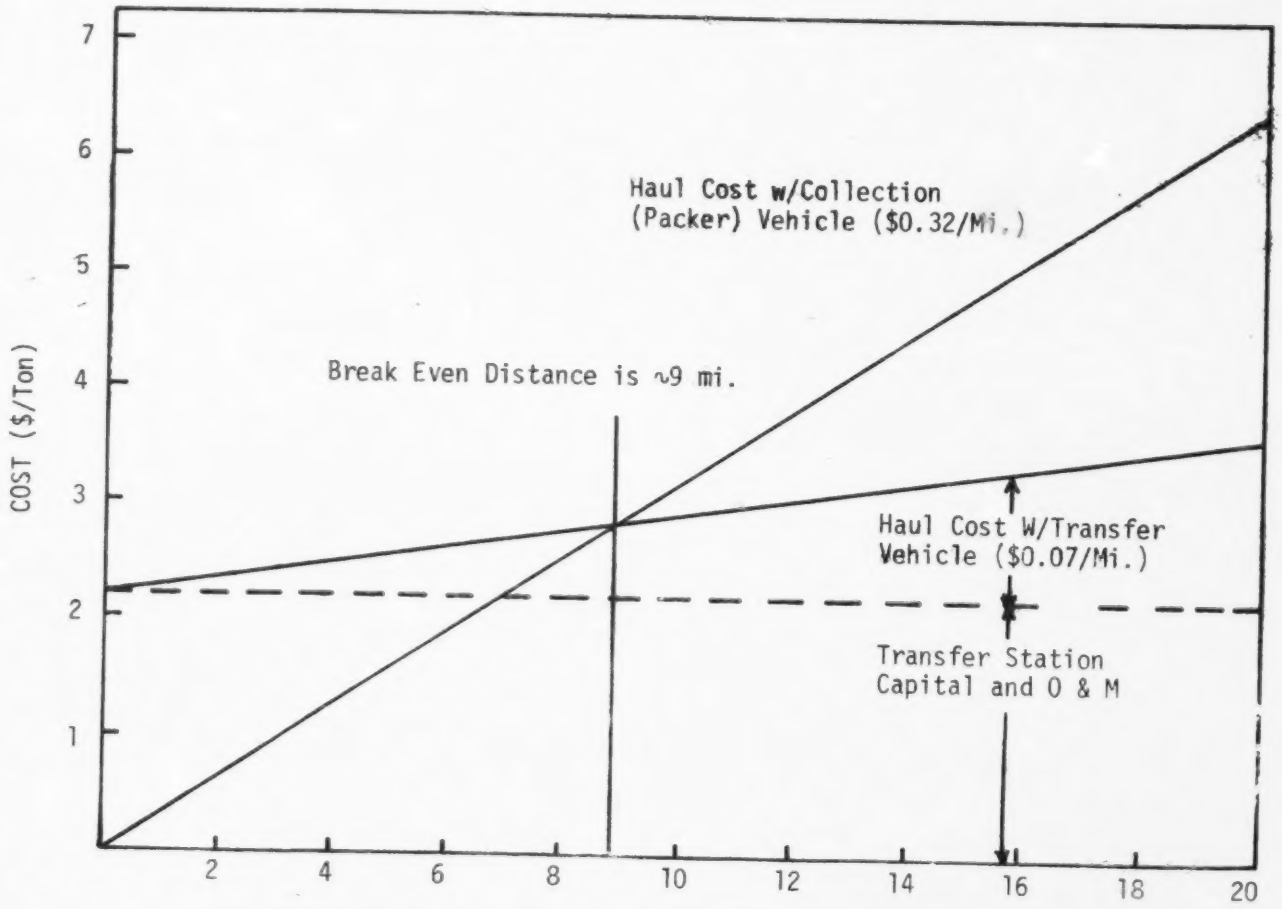
Total Annual Cost of Baling Facility and Balefill = $133,000/yr

Based on the estimates made here it is concluded that large scale baling of the refuse collected in Murray is not at this time an economically viable alternative.

FIGURE IX-1

ECONOMICS OF REFUSE TRANSFER

VERSUS HAUL WITH PACKER VECHICLE



APPENDIX A

ESTIMATE OF CURRENT POPULATION

For the p poses of this study it was necessary to make an estimate of the current oulation of Murray, Ky. Population counts were obtained from the U. S. reau of Census for three separate counts. The Murray Chamber of Commerce provided utility customer counts corresponding to the three censuses This data is presented graphically in Figure A-1. It can be seen that there is fairly good correlation between utility customer count and population for the city. Based on functions derived from a least squares analysis, the population as of January 1, 1979 was approximately 15,100. This figure will be used for this report.

Murray State University (MSU) is responsible for the collection and transport of its own solid waste to the municipal landfill. Thus the full-time students living on campus (included in the city's population count) are not serviced by the City of Murray Sanitation Department. Information provided by the MSU Office of Housing is as follows:

Full-time students living on campus - Spring semester, 1979:

Dormitories - 2,830

Married student housing - 315 (including spouses and children)

The city population served by the sanitation department is then:

15,100 - 2,830 - 315 = 11,955
= 12,000

The Murray Sanitation Department serves a number of households outside of the city limits. The total number of people served will be approximated in the following way:

City Billings (May, 1979) = 3,680

County Billings (May, 1979) = 89

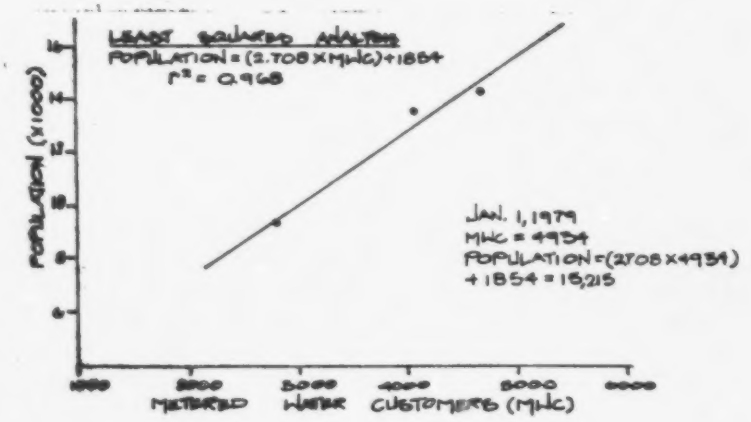
Total Billings = 3,680 + 89 = 3,769

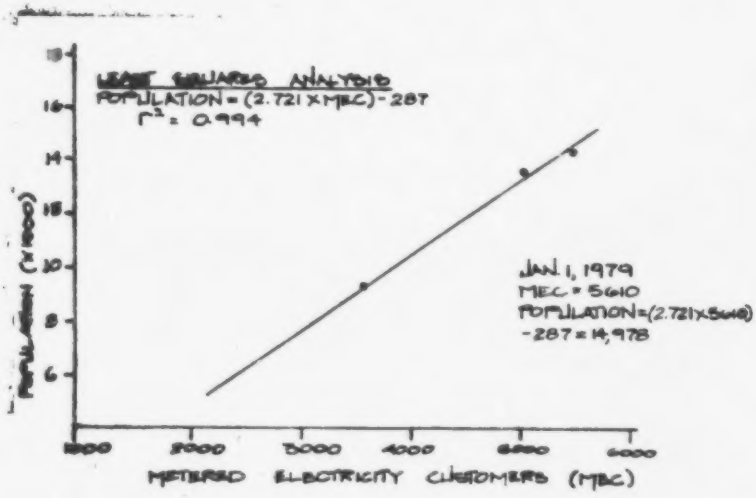
Approximate total population served = (3,769/3,680) x 11,955
= 12,200

CENSUS POPULATION AS FUNCTION OF UTILITY CONNECTIONS - MURRAY, KY.

FIGURE A-1

(Information from U.S. Census Bureau and Murray Chamber of Commerce)


LEAST SQUARED ANALYSIS
POPULATION = (2.708 X MWC) + 1854
r² = 0.968
Jan. 1, 1979
MWC = 4934
POPULATION = (2708 X 4934)
+ 1854 = 15,215
METERED WATER CUSTOMERS (MWC)


LEAST SQUARED ANALYSIS
POPULATION = (2.721 X MEC) - 287
r² = 0.994
JAN. 1, 1979
MEC = 5610
POPULATION = (2.721 X 5610)
- 287 = 14,978
METERED ELECTRICITY CUSTOMERS (MEC)

APPENDIX B

COST AND PRODUCTIVITY ESTIMATE

FOR PRESENT SOLID WASTE COLLECTION PROGRAM

Equipment Capital Costs

Assume that eventual replacement of the currently used 18 cu. yd. packer truck will be with a 25 cu. yd. rear end packer.

Packer Truck - 25 cu. yd.

Based on information provided by Atlanta, Georgia and Louisville, Kentucky equipment dealers, the 1979 cost of a packer body/chasis unit equivalent to the ones currently used by the City of Murray is approximately $53,000.

Satellite Collection Vehicle - 1.6 cu. yd.

Based on information provided by Atlanta, Georgia equipment dealer, the 1979 cost of satellite vehicle equivalent to the ones currently used by the City of Murray is $6,140.

Estimate of Total Equipment Cost

Age of Vehicle (years)	Trade-in Value (% delivery price)	Yearly debt Cost (% of avg. worth)	Maintenance (% of delivery price)	Availability Factor (%)	Productivity Factor (%)
		5-YEAR VEHICLE LIFE			
1	75	12	4.5	95	98
2	55	12	6.5	94	96
3	40	12	10.5	91	14
4	30	12	16.5	88	92
5	25	12	22.5	85	90
		3-YEAR VEHICLE LIFE*			
1	60	12	5	94	97
2	17	12	12	90	93
3	25	12	22	85	90

*(developed from 5-year figures)

Table B-1 gives the life cycle costs for the 25 cu. yd. packer truck.

Average yearly cost = 111,420/5 = $22,284/year

Assume 7.5 hr/day operation (Monday - Thursday), 4 hr. (Friday), 52 wk/yr

$$\frac{22,284}{[(7.5 \times 4) + 4] \times 52} = \$12.6/hr$$

Table B-2 gives the life cycle costs for the 1.6 cu. yd. satellite vehicle

Average yearly cost 11,712/3 - $3,904/year

$$\frac{\$3,904}{[(7.5 \times 4) + 4] \times 52} = \$2.2/hr$$

Total collection vehicle cost = 12.6 + 2.2 = $14.8/hr

Estimate of Labor Cost

Based on pay scale provided by J. Wallace, Superintendent of Sanitation, Murray

1 Residential Truck Driver	-	$4.40/hr
2 Walkers @ $4.03/hr	-	$8.06/hr
1 Cushman Driver/Collector	-	$4.03/hr*
Total	-	$16.49/hr

Assume total fringe benefits - 18.3% of wage

Assume personnel overhead (supervision, accounting, etc.) - 13.1% of wage

Hourly labor cost - $16.49 (1 + 0.183 + 0.131) = $21.7/hr

Cost and Productivity Factors

Total yearly cost for collection** =

{[(7.5 x 4) + 4] X 52 X $14.8} + (40 X 52 X $21.7) =$71,300/yr

Total daily cost for collection system =

($21.7/hr X 8 hr) + ($14.8/hr X 7.5 hr) = $285/day

*Currently the satellite vehicle driver/collectors are being paid at an average $3.80/hr. It is assumed here that over the long run they will be paid the same as walkers.

**Does not include cost for motor-pool facility. Based on 34 hr/wk equipment usage; 40 paid hours.

TABLE B-1 LIFE CYCLE COSTS - 25 CU. YD. REAR LOADER PACKER TRUCK

Year:	1	2	3	4	5
Capital Investment and Depreciation:					
Trade-in value (% of delivery price)	75	55	40	30	25
Investment, start of year ($)	53,000	39,750	29,150	21,200	15,900
Year-end value ($)	39,750	29,150	21,200	15,900	13,250
Yearly capital cost ($)	13,250	10,600	7,950	5,300	2,650
Debt Service and Insurance:					
Average yearly worth ($)	46,375	34,450	25,175	18,550	14,575
Yearly debt cost @ 12% ($)	5,565	4,134	3,021	2,226	1,749
Maintenance:					
Yearly estimated (% of delivery price)	4.5	6.5	10.5	16.5	22.5
Yearly estimated cost ($)	2,385	3,445	5,565	8,745	11,925
Fuel and Oil ($)	1700	1700	1700	1700	1700
Downtime:					
Availability factor	95	94	91	88	85
Hours not available (1)	94	112	168	225	281
Cost @ $10/hr	940	1,120	1,680	2,250	2,810
Reserve vehicle ($)					
Obsolescence:					
Productivity factor	98	96	94	92	90
Extra hours required to match Production of new model(1)	37	75	112	150	187
Cost @ $10/hr ($)	370	750	1,120	1,500	1,870
Total Annual Cost ($)	24,210	21,749	21,036	21,721	22,704
Cumulative Vehicle Cost ($)	24,210	45,959	66,995	88,716	111,420

(1) Based on 36 hours/week

TABLE B-2 - LIFE CYCLE COSTS - 25 CU. YD. REAR LOADER PACKER TRUCK

Year:	1	2	3	4	5
Capital Investment and Depreciation:					
Trade-in value (% of delivery price)	60	37	25		
Investment, start of year ($)	6,140	3,684	2,272		
Year-end value ($)	3,684	2,272	1,535		
Yearly capital cost ($)	2,456	1,412	737		
Debt Service and Insurance:					
Average yearly worth ($)	4,912	2,978	1,904		
Yearly debt cost @ 12% ($)	589	357	228		
Maintenance:					
Yearly estimated (% of delivery price)	5	12	22		
Yearly estimated cost ($)	307	737	1351		
Fuel and Oil ($)	550	550	550		
Downtime:					
Availability factor	94	90	85		
Hours not available (1)	112	187	281		
Cost @ $10/hr					
Reserve vehicle ($)	224	374	562		
Obsolescence:					
Productivity factor	97	93	90		
Extra hours required to match					
Production of new model(1)	55	127	182		
Cost @ $10/hr ($)	110	254	364		
Total Annual Cost ($)	4,236	3,684	3,792		
Cumulative Vehicle Cost ($)	4,236	7,920	11,712		

(1) Based on 36 hours/week

Cost to route = Total cost X $\frac{\text{Average time to route}}{\text{Average total time worked}}$ =

$\frac{\$285}{\text{day}}$ X $\frac{0.10 \text{ hr/day}}{6.6 \text{ hr/day}}$ = \$4.3/day

Cost to collect = Total cost X $\frac{\text{Average time to collect}}{\text{Average total time worked}}$ =

$\frac{\$285}{\text{day}}$ X $\frac{5.76 \text{ hr/day}}{6.6 \text{ hr/day}}$ = \$248.7/day

Cost transport to landfill = total cost X $\frac{\text{Average time to transport}}{\text{Average total time worked}}$ =

$\frac{\$285}{\text{day}}$ X $\frac{0.78 \text{ hr/day}}{6.6 \text{ hr.day}}$ = \$33.7/day

Cost per home served (per week) =

$\frac{\text{Total Cost (per day) X frequency of collection (per week)}}{\text{Average homes served (per day)}}$ =

$\frac{(\$285/\text{day}) \text{ X } (1/\text{wk})}{490/\text{day}}$ = \$0.58/wk per residence (total collection service)

Assumed average weight of solid waste collected - 16.5 ton/day
(7-day/wk basis)

Average weight per pick-up - $\frac{(16.5 \text{ ton/day}) \text{ X } (7 \text{ day/wk}) \text{ X } (2000 \text{ lb/ton})}{4300 \text{ pick-up}}$

= 53.7/lb/pick-up

$\frac{53.7 \text{ lb}}{\text{pick-up}}$ X $\frac{490 \text{ pick-up}}{\text{day-crew}}$ X $\frac{\text{ton}}{2000 \text{ lb}}$ = $\frac{13.2 \text{ ton}}{\text{day-crew}}$

Approximately 13.2 tons per full collection per day per crew is collected (assuming crews equivalent to East crew)

Cost per ton = $\frac{\text{Total Costs}}{\text{Tons collected}}$ = $\frac{\$285/\text{day}}{13.2 \text{ ton/day}}$ = \$21.6/ton

Collection cost per home served (per week) =

$\frac{\text{Collection Costs (per day) X Frequency of Collection (Per wk)}}{\text{Average Homes Served (per day)}}$ =

$\frac{(\$248.7/\text{day}) \text{ X } (1/\text{wk})}{490/\text{day}}$ = \$0.51/wk

Collection cost per ton = $\frac{\text{Collection costs}}{\text{Average tons collected}}$ = $\frac{248.7/\text{day}}{13.2 \text{ ton/day}}$ = \$18.8/ton

Productivity Factors

$$\text{Services/crew/collection hour} = \frac{490 \text{ pick-up/day}}{5.76 \text{ hr/day}} = 85$$

$$\text{Tons/crew/collection hour} = \frac{13.2 \text{ ton/day}}{5.76 \text{ hr/day}} = 2.3$$

$$\text{Services/collector/collection hour} = \frac{490 \text{ pick-up/day}}{5.76 \text{ hr/day} \times 3} = 28$$

$$\text{Tons/collector/collection hour} = \frac{13.2 \text{ ton/day}}{5.76 \text{ hr/day} \times 3} = 0.8$$

APPENDIX C

NORMALIZATION OF SOLID WASTE COLLECTION COST FOR COMPARISON SYSTEMS

The purpose of this section is to put the costs of solid waste collection for a number of different systems on a basis such that they are comparable to those estimated for Murray's system (see Appendix B). The systems to be compared were the subject of a comprehensive, year-long study which was published in March, 1975, Residential Collection Systems, (EPA/530/SW-97c.1). The systems studied were selected as being "highly productive".

Estimate of Delivery Price of Collection Vehicles

Table C-1 gives the estimated delivery prices for the packer trucks used by the collection systems (A through H). The 1972 prices were adjusted to 1979 by the ratio of the 1979 25 cu. yd. price to the 1972 25-cu. yd. price (53,000/23,900 = 2.12). It should be noted that for systems F and H, all packers were not of the same size. The data will be adjusted to reflect only the units of consistent size.

Estimate of Capital Costs

Tables C-2 and C-3 give the life cycle costs for the 20 and 13 cu. yd., rear loaded vehicles. See Appendix B for life cycle costs for 25 cu. yd. rear load (RL) and side load (SL) vehicles.

The costs for the reference collection systems will be put on the same usage basis (see Appendix B) to allow comparison with Murray's system.

20 cu. yd. - RL

Average yearly cost = $106,414/5 = \$21,283/yr$

$$\frac{21,283}{[(7.5 \times 4) + 4] \times 52} = \$12.0/hr$$

13 cu. yd. - RL

Average yearly cost = $81,366/5 = \$16,273/yr$

$$\frac{16,273}{[(7.5 \times 4) + 4] \times 52} = \$9.2/hr$$

Estimate of Labor Costs

Table C-4 gives the labor costs for the reference collection systems. These costs are based on the same hourly wage, fringe benefit rate, and personnel overhead rate as those used for the Murray system (see Appendix B).

TABLE C-1

ESTIMATED DELIVERY PRICE OF

PACKER COLLECTION TRUCKS

System	Type	Size	Cost - 1972	Cost - 1979
A	SL	25 cu.yd.	$23,900	$53,000
B	SL	25	23,900	53,000
C	RL	20	22,700	50,300
D	RL	25	23,900	53,000
E	RL	20	22,700	50,300
F*	RL	25	23,900	53,000
G	RL	20	22,700	50,300
H*	RL	13	15,900	35,300

Legend: SL = Side loader
RL = Rear loader
$ '79 = $ '72 X 53,000/23,900

* 3 of 4 vehicles this size

TABLE C-2: LIFE CYCLE COSTS - 20 CU. YD. , REAR LOAD PACKER TRUCK

Year:	1	2	3	4	5
Capital Investment and Depreciation:					
Trade-in value (% of delivery price)	75	55	40	30	25
Investment, start of year ($)	50,300	37,725	27,665	20,120	15,090
Year-end value ($)	37,725	27,665	20,120	15,090	12,575
Yearly capital cost ($)	12,575	10,060	7,545	5,030	2,515
Debt Service and Insurance:					
Average yearly worth ($)	44,013	32,695	23,893	17,605	13,833
Yearly debt cost @ 12% ($)	5,282	3,923	2,867	2,113	1,660
Maintenance:					
Yearly estimated (% of delivery price)	4.5	6.5	10.5	16.5	22.5
Yearly estimated cost ($)	2,264	3,270	5,282	8,300	11,318
Fuel and Oil ($)	1600	1600	1600	1600	1600
Downtime:					
Availability factor	95	94	91	88	85
Hours not available (1)	94	112	168	225	281
Cost @ $10/hr					
Reserve vehicle ($)	940	1,120	1,680	2,250	2,810
Obsolescence:					
Productivity factor	98	96	94	95	90
Extra hours required to match					
Production of new model(1)	37	75	112	150	187
Cost @ $10/hr ($)	370	750	1,120	1,500	1,870
Total Annual Cost ($)	23,031	20,723	20,094	20,793	21,773
Cumulative Vehicle Cost ($)	23,031	43,754	63,848	84,641	106,414

(1) Based on 36 hours/week

TABLE C-3 LIFE CYCLE COSTS - 13 CU. YD. REAR LOAD PACKER TRUCK

Year:	1	2	3	4	5
Capital Investment and Depreciation:					
Trade-in value (% of delivery price)	75	55	40	30	25
Investment, start of year ($)	35,300	26,475	19,415	14,120	10,590
Year-end value ($)	26,475	19,415	14,120	10,590	8,825
Yearly capital cost ($)	8,825	7,060	5,295	3,530	1,765
Debt Service and Insurance:					
Average yearly worth ($)	30,888	22,945	16,768	12,355	9,708
Yearly debt cost @ 12% ($)	3,707	2,753	2,012	1,485	1,165
Maintenance:					
Yearly estimated (% of delivery price)	4.5	6.5	10.5	16.5	22.5
Yearly estimated cost ($)	1,589	2,295	3,707	5,825	7,943
Fuel and Oil ($)	1600	1600	1600	1600	1600
Downtime:					
Availability factor	95	94	91	88	85
Hours not available (1)	94	112	168	225	281
Cost @ $10/hr					
Reserve vehicle ($)	940	1,120	1,680	2,250	2,810
Obsolescence:					
Productivity factor	98	96	94	92	90
Extra hours required to match					
Production of new model(1)	37	75	112	150	187
Cost @ $10/hr ($)	370	750	1,120	1,500	1,870
Total Annual Cost ($)	17,031	15,578	15,414	16,190	17,153
Cumulative Vehicle Cost ($)	17,031	32,609	48,023	64,213	81,366

(1) Based on 36 hours/week

Normalization of System Costs

Tables C-5 and C-6 show the data generated to put the costs and performance factors for the reference systems on a comparable basis with Murray's system. The basic methodology used here was to take performance measured during the year long study (services/hr, tons collected/hr, etc.) and apply them to task times equivalent to the Murray system and costs comparable to the Murray system.

Cost Performance and Productivity

Table C-7 gives the cost performance and productivity factors for the reference systems on a basis comparable to the Murray system. Calculations are done using the same procedure as that used in Appendix B.

TABLE C-5: MURRAY EQUIVALENT TASK COSTS FOR STUDY SYSTEMS

System	Daily Costs[1]			Time (per day)[2]			Task Costs (per day)[3]		
	Labor ($)	Equipment ($)	Total ($)	To Route (hr)	Collection (hr)	Transport (hr)	To Route ($)	Collection ($)	Transport ($)
A	46.4	94.5	141	0.10	5.76	0.78	2.1	122.3	16.6
B	46.6	94.5	141	0.10	5.76	0.78	2.1	122.3	16.6
C	88.8	90.0	179	0.10	5.17	1.37	2.7	139.4	36.9
D	88.8	94.5	183	0.10	5.76	0.78	2.8	158.7	21.5
E	131.2	90.0	221	0.10	5.17	1.37	3.3	172.1	45.6
F	131.2	94.5	226	0.10	5.76	0.78	3.4	196.0	26.5
G	88.8	90.0	179	0.10	5.17	1.37	2.7	139.4	36.9
H	88.8	69.0	158	0.10	5.17	1.37	2.4	123.0	32.6

(1) Same basis as Murray's system - 8 hr/day labor; 7.5 hr/day equipment.

(2) 25 cu. yd. RL and SL - same as East crew

13 and 20 cu. yd. RL - same as West crew with adjustment such that extra landfill time is deducted from collection time ("other" task time in Table III-3 is assumed equivalent). "To Route" time is also assumed equivalent.

(3) Task cost = total daily cost X $\frac{\text{Task time}}{\text{Time required for all tasks}}$

TABLE C-6: CONVERSION FROM ACTUAL PERFORMANCE TO MURRAY EQUIVALENT PERFORMANCE FOR STUDY SYSTEMS

System	Actual Performance (1)					Murray Equivalent Performance (2)	
	Pick-ups per day	Tons Collected per day	Hours Worked per day (3)	Pick-ups per hr	Tons Collected per hr	Pick-ups per day	Tons Collected per day
A	410	9.4	3.83	107	2.5	616	14.4
B	254	9.0	4.54	56	2.0	323	11.5
C	512	12.6	4.81	106	2.6	548	13.4
D	575	14.5	4.68	123	3.1	709	17.9
E	407	12.7	3.81	107	3.3	553	17.1
F	332	9.9	4.87	68	2.0	392	11.5
G	364	6.2	5.06	72	1.2	372	6.2
H	244	6.2	5.40	45	1.1	233	5.7

(1) Average measured during year-long study.

(2) Based on measured hourly performance and Murray working schedule (see Table C-5).

(3) Collection time only.

TABLE C-7: COST PERFORMANCE AND PRODUCTIVITY FACTORS[1]

System	Cost per home, per week ($)	Cost per ton ($)	Collection Cost per home per week ($)	Collection Cost per ton ($)	Homes Served[2] collector per collection hr.	Tons per[2] collector per collection hr.
A	0.23	9.8	0.20	8.5	107	2.5
B	0.44	12.3	0.38	10.6	56	2.0
C	0.33	13.4	0.25	10.4	107	2.6
D	0.26	10.2	0.22	8.9	116	2.9
E	0.40	12.9	0.31	10.1	52	1.6
F	0.58	19.7	0.50	17.0	34	1.0
G	0.48	28.9	0.37	22.5	70	1.2
H	0.68	27.7	0.53	21.6	45	1.1

(1) All factors using Murray equivalent costs and working schedule.

(2) For the case where 1-man crew is used the driver is also the collector. For 2 and 3 man crews all except the driver are collectors.

FIGURE D-1

RESIDENTIAL COLLECTION ROUTE A

A

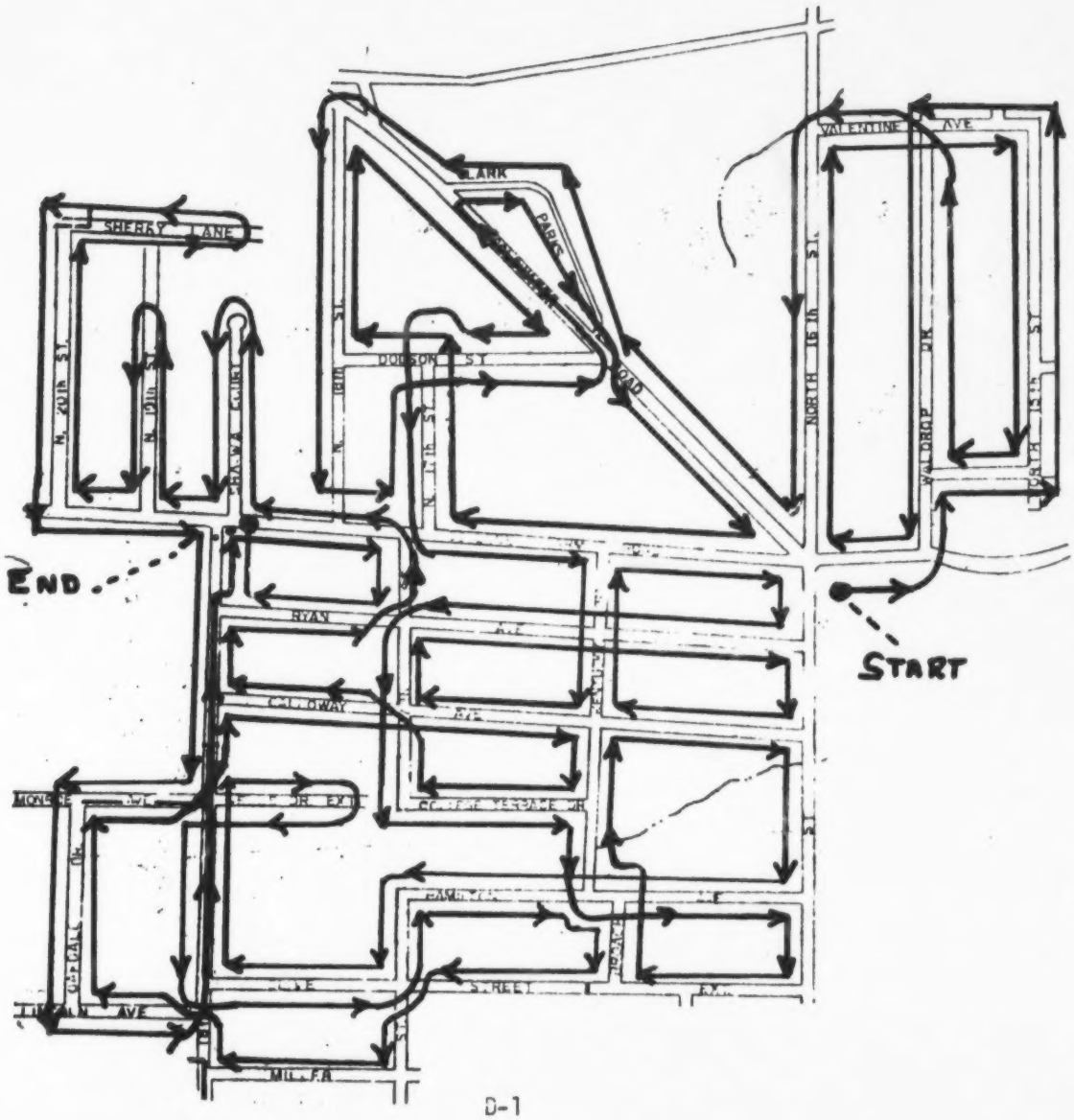


FIGURE D-2

RESIDENTIAL COLLECTION ROUTE B

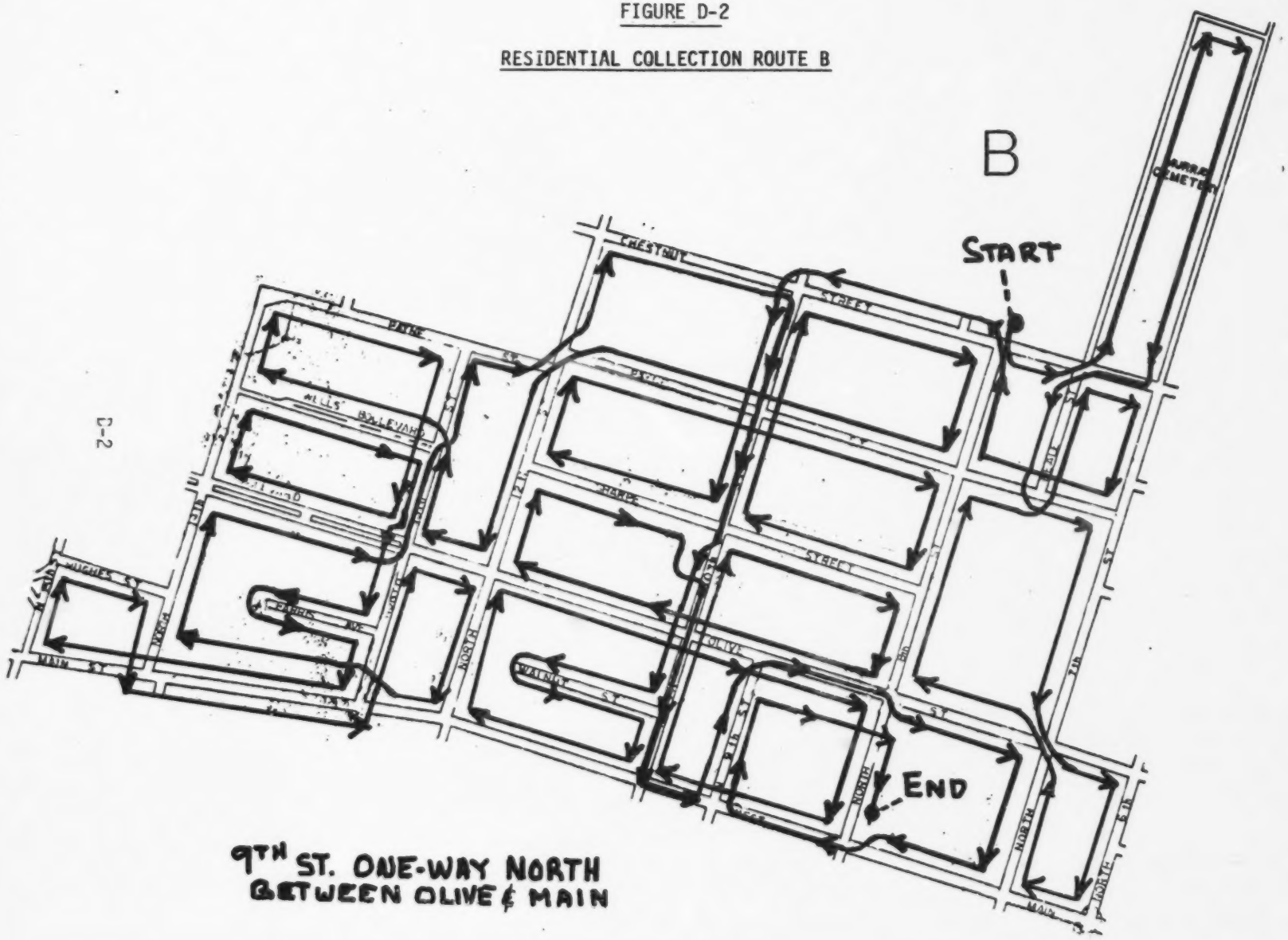


FIGURE D-3

RESIDENTIAL COLLECTION ROUTE C

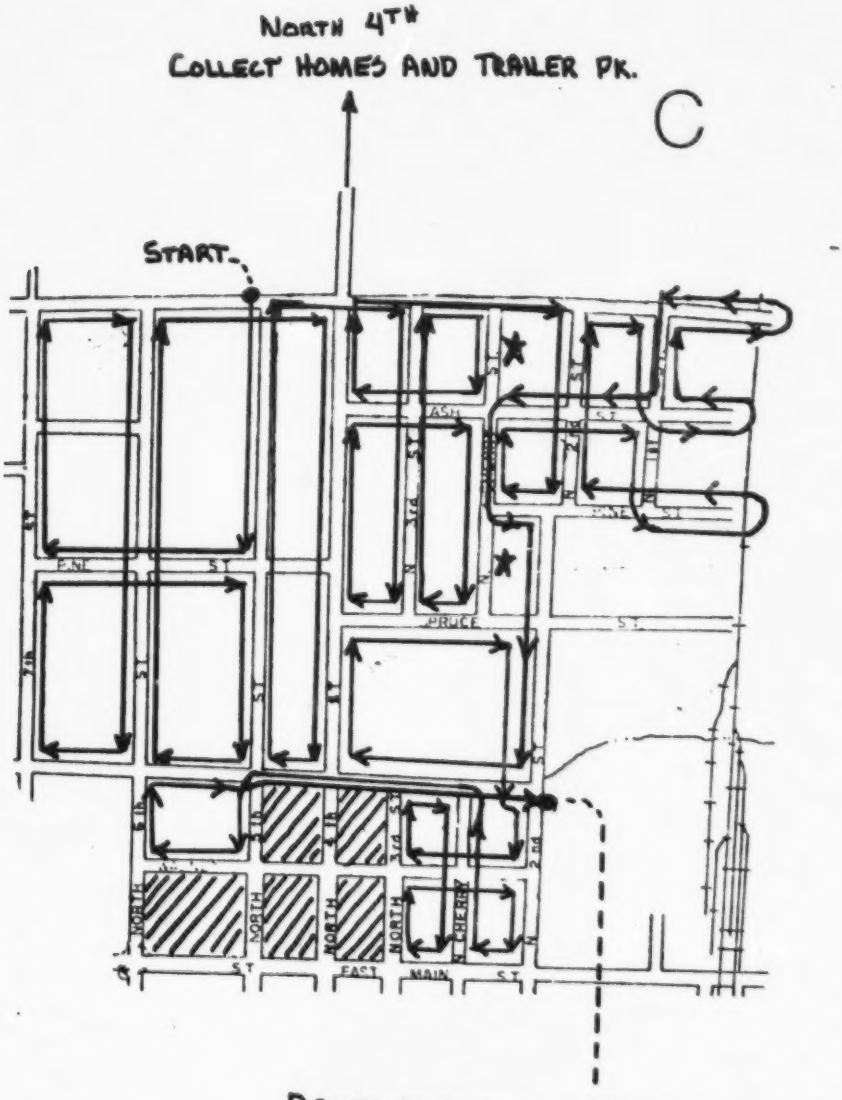
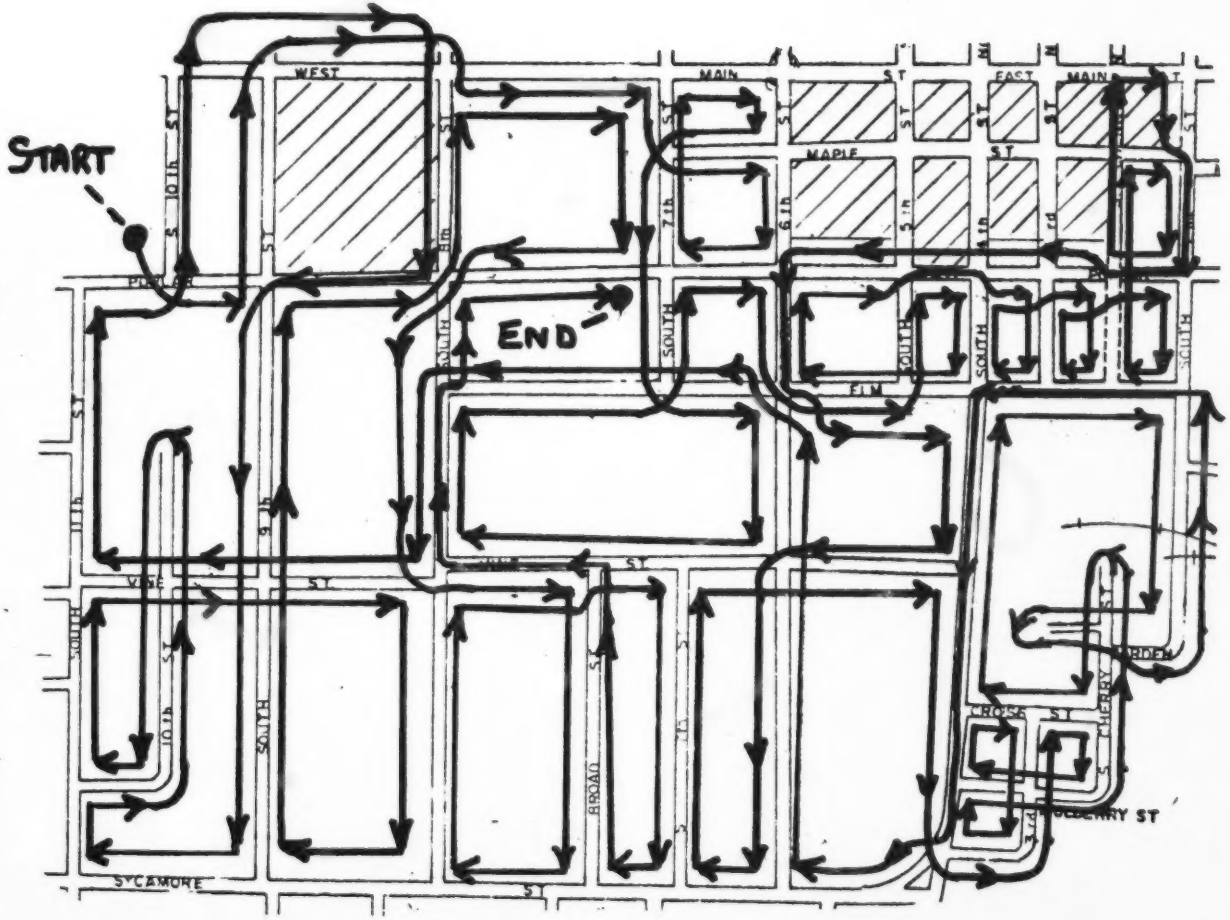


FIGURE D-4

RESIDENTIAL COLLECTION ROUTE D

9TH ST. ONE-WAY NORTH
BETWEEN MAIN AND POPLAR

D



N

FIGURE D-5

RESIDENTIAL COLLECTION ROUTE E

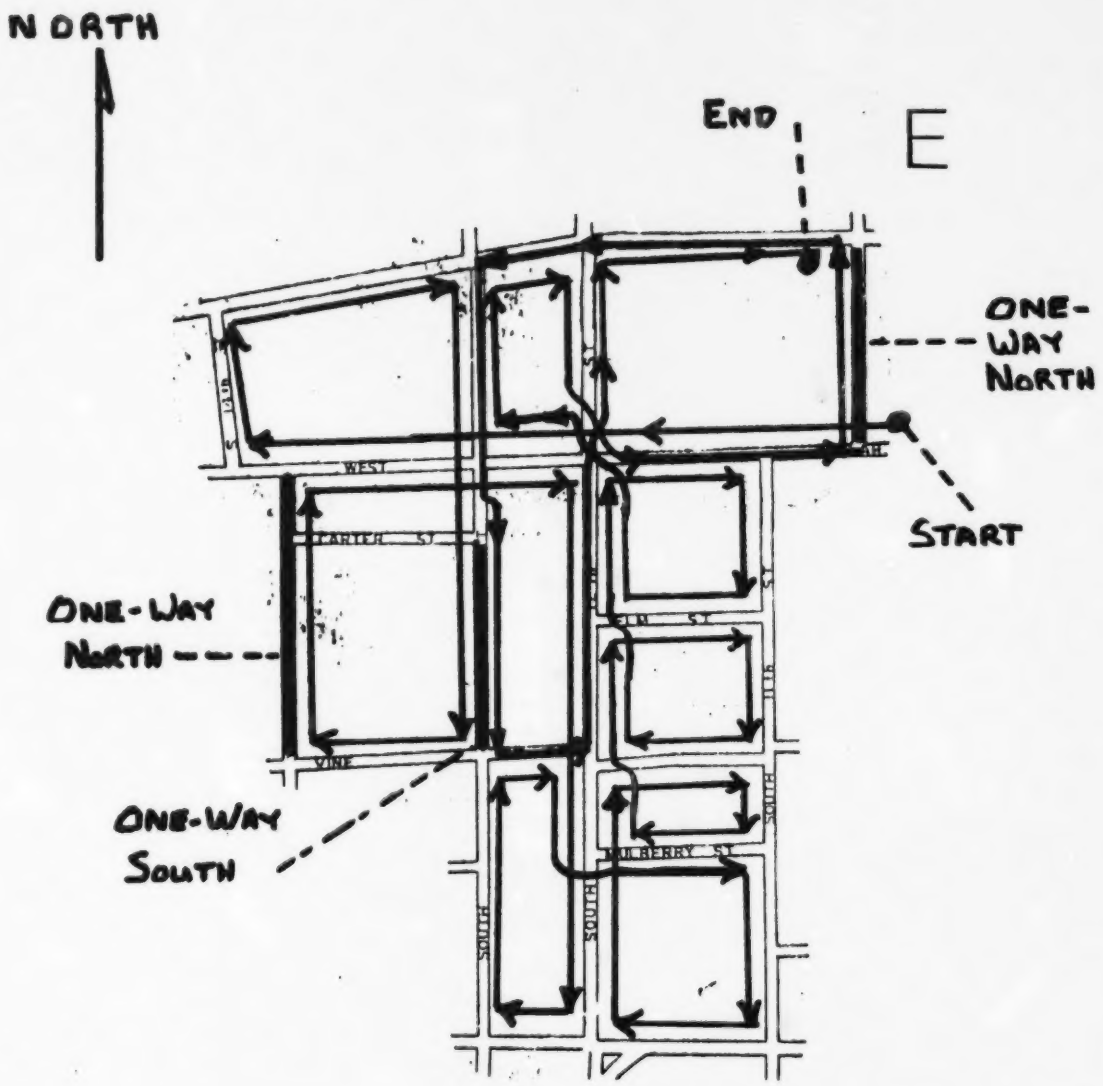


FIGURE D-6

RESIDENTIAL COLLECTION ROUTE F

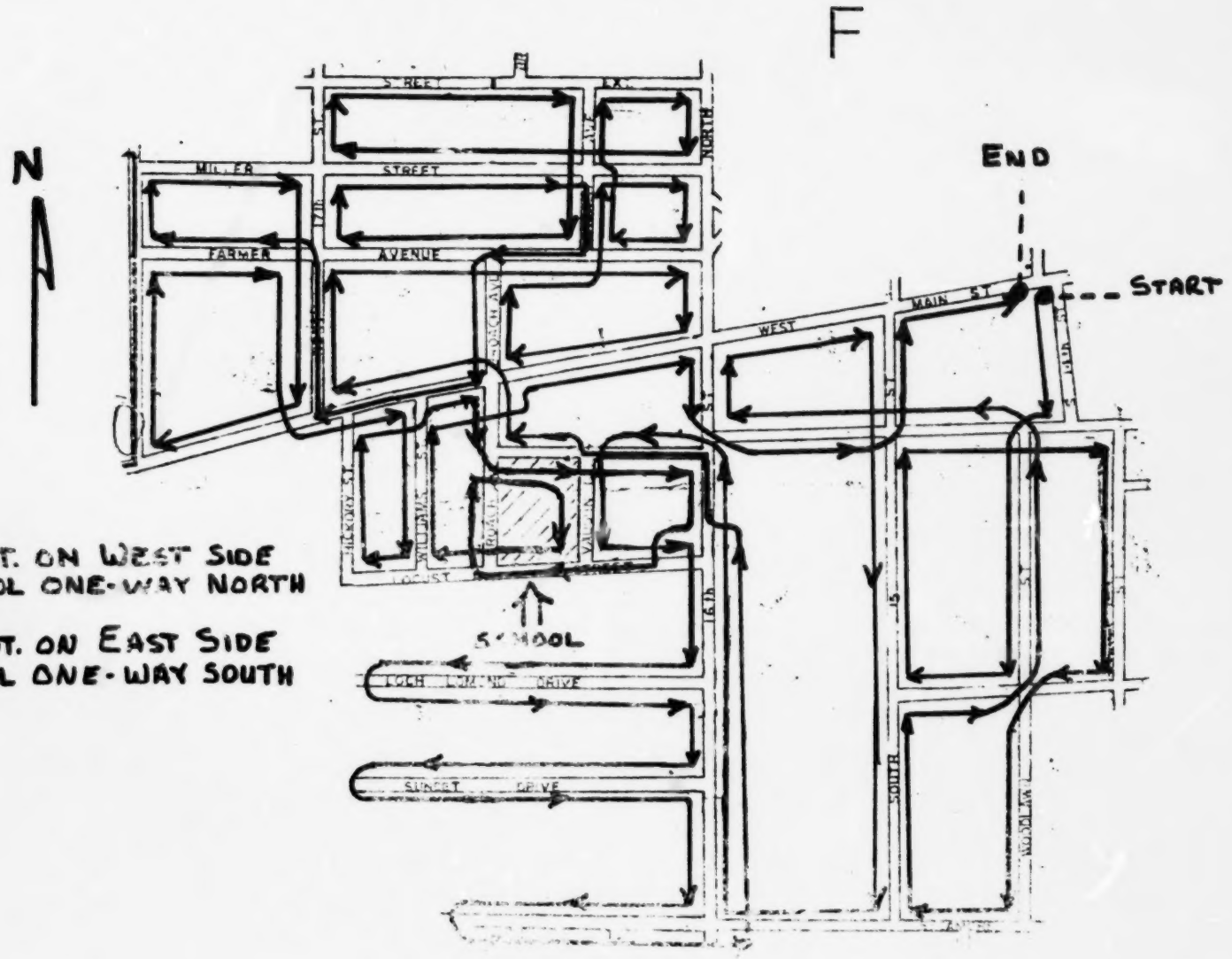


FIGURE D-7

RESIDENTIAL COLLECTION ROUTE G

G

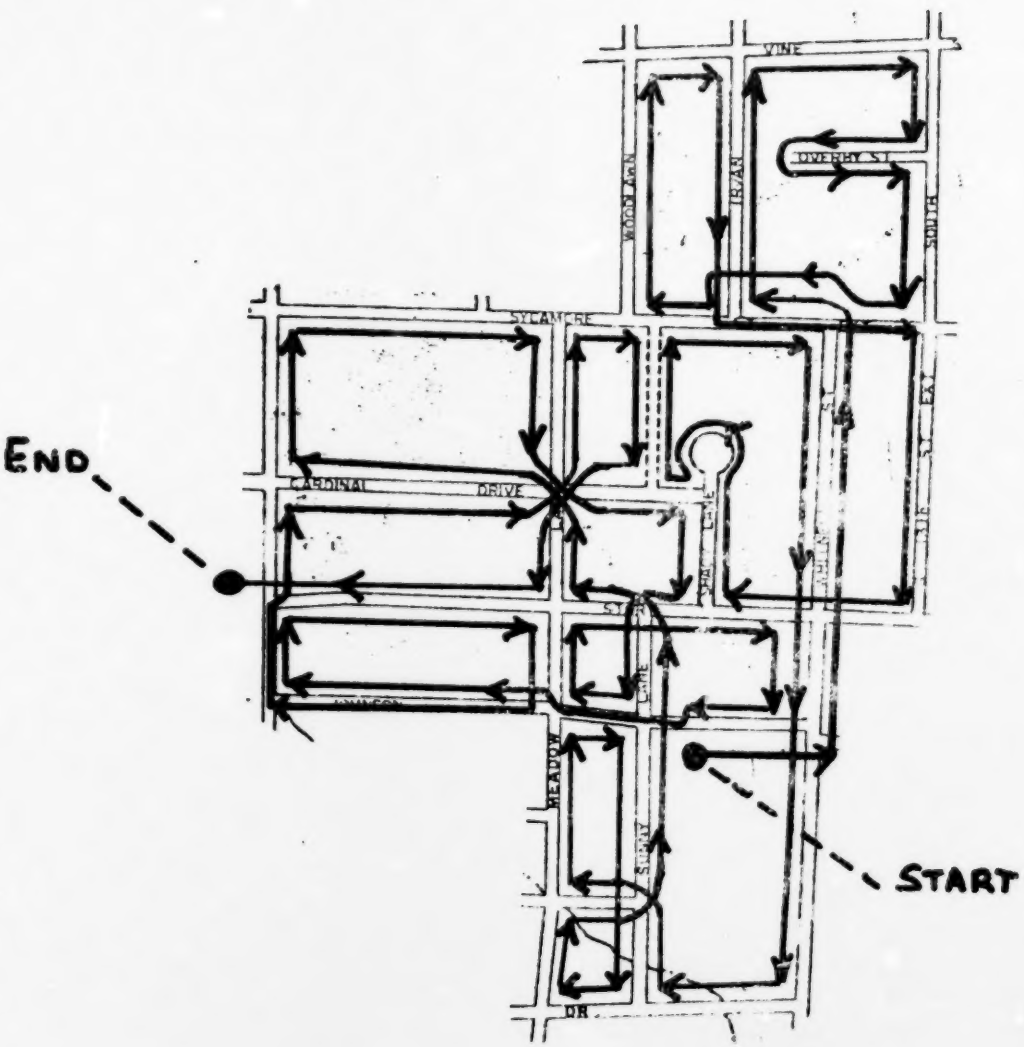


FIGURE D-8

RESIDENTIAL COLLECTION ROUTE H

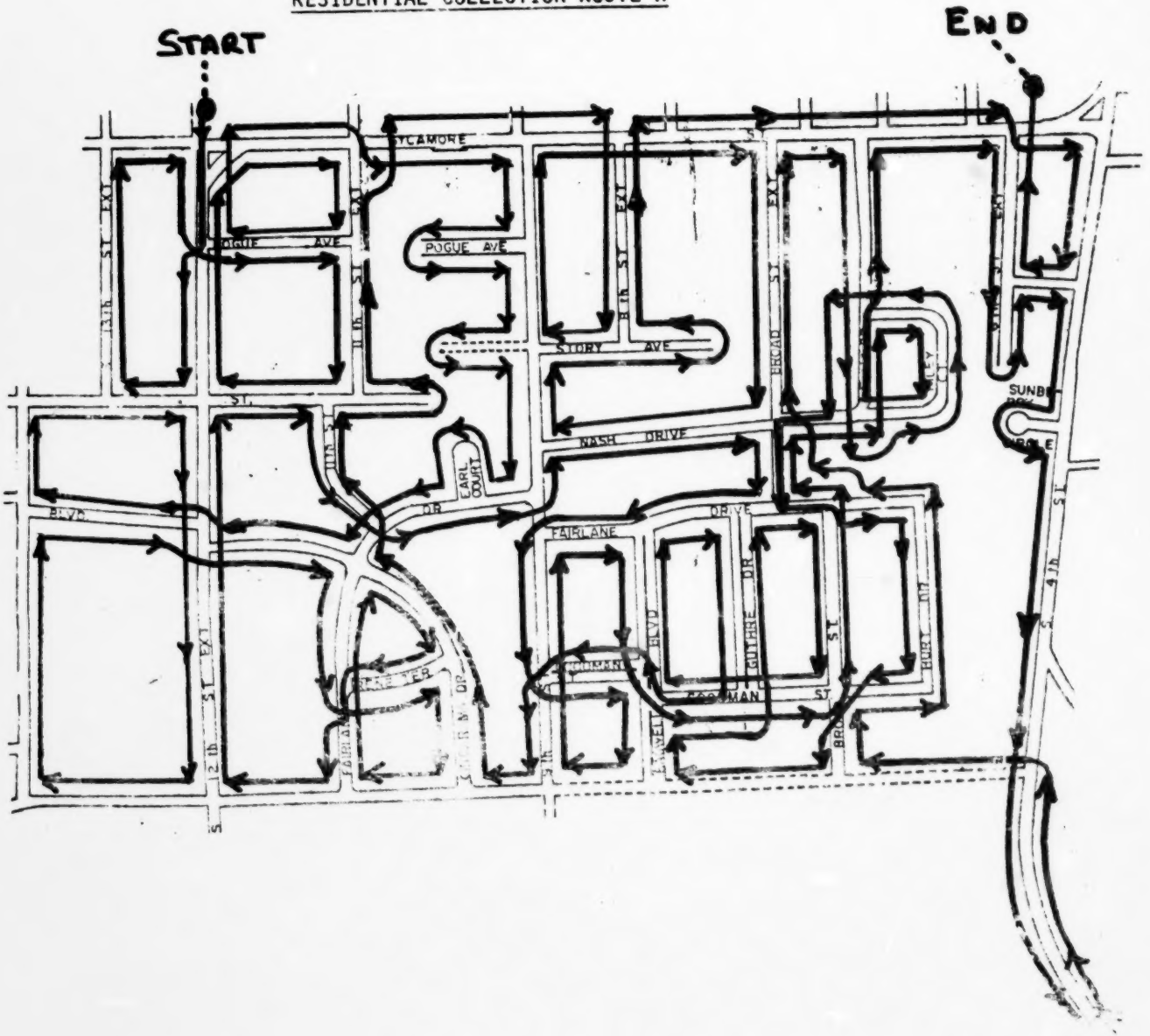


FIGURE D-9

RESIDENTIAL COLLECTION ROUTE I

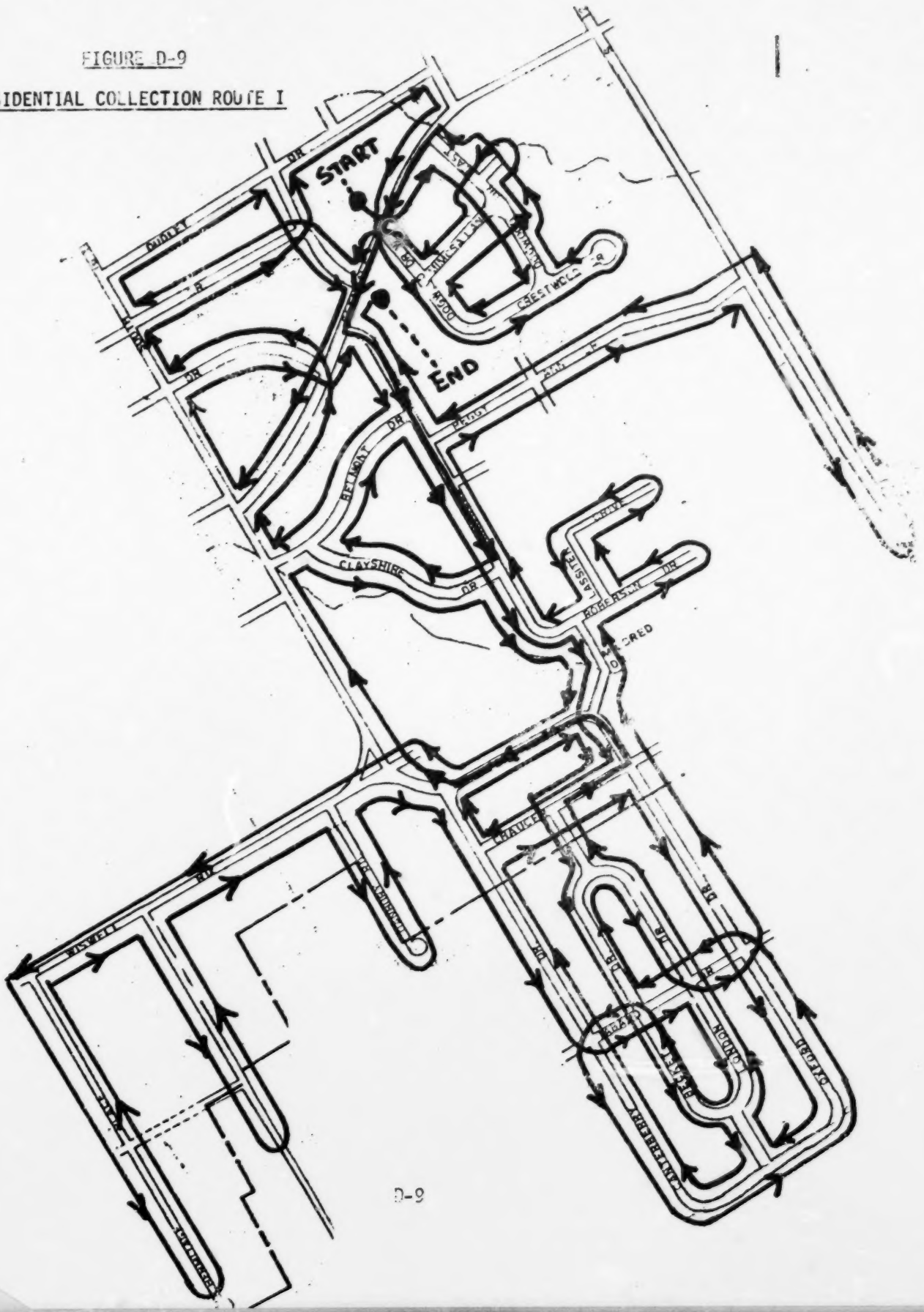
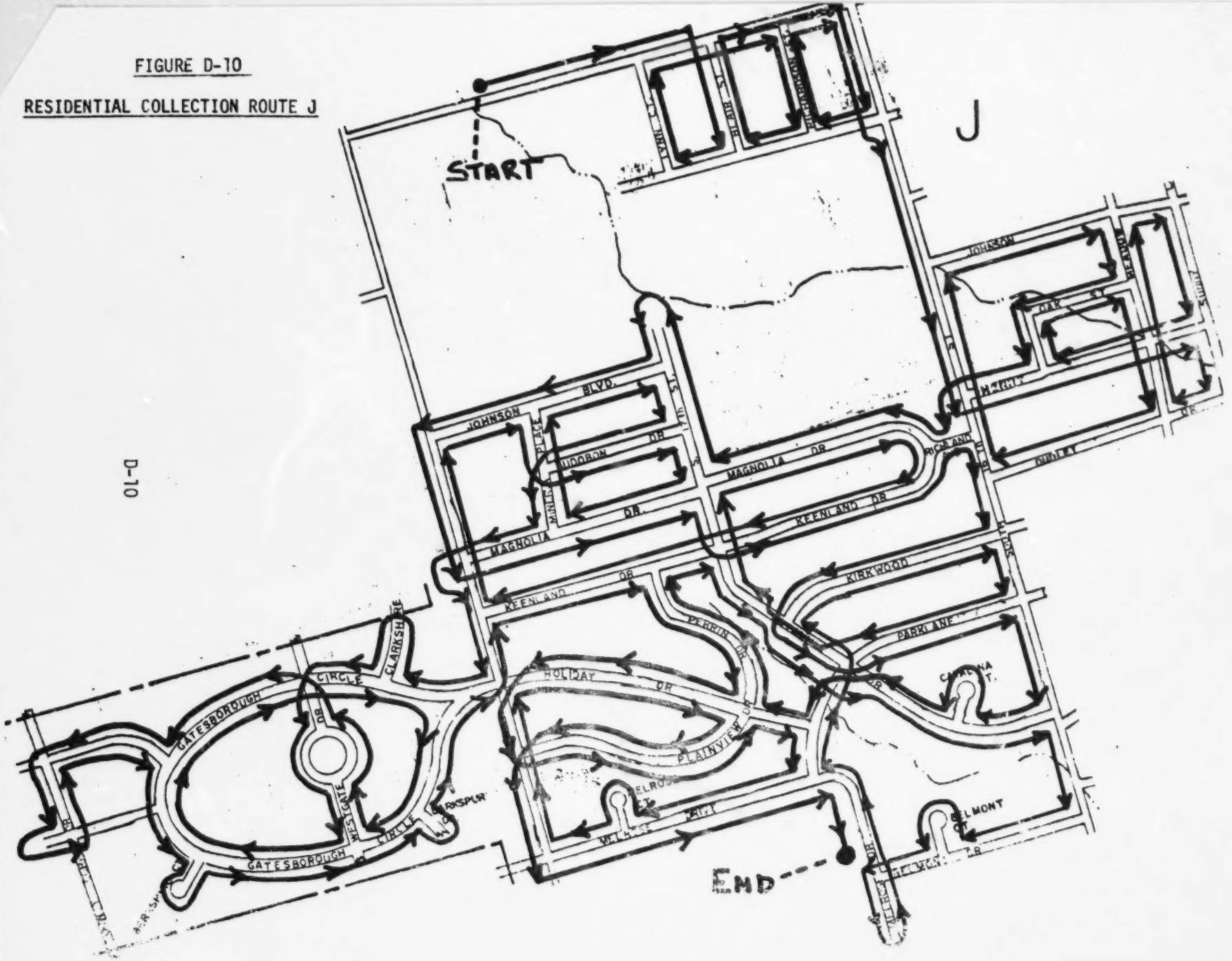


FIGURE D-10

RESIDENTIAL COLLECTION ROUTE J



APPENDIX E

COMMERCIAL COLLECTION COST ESTIMATES

Front Loaded Bins and Collection Vehicle

Estimates for commercial collection crew using a 25-cu. yd., front load packer vehicle.

Equipment Costs

Based on estimates obtained from three heavy equipment vendors, the approximate current (August 1979) initial cost for a good quality 25 cu. yd., front load packer truck are as follows:

Body	-	$25,000
Chassis	-	43,000
Total	-	$68,000

The life cycle costs for the vehicle are given in Table E-1.

Average Yearly Cost = $\frac{137,470}{5}$ = $27,495/yr.

Annual Equipment Cost = $27,500/yr.

Labor

Assume two person crew (based on current pay scale):

Driver @	-	$4.60/hr.
Helper @	-	4.34/hr.
Total Wage	-	$8.94/hr.

Assume 18.3% fringe benefits and 13.1% personnel overhead

Total labor = $8.94 (1 + 0.183 + 0.131) = $11.7/hr.

Annual labor cost (40 hr./wk., 52 wk./yr.)
= 40 x 52 x 11.7 = $24,300/yr.

Storage Containers

A group of companies who manufacture front load type refuse storage bins were contacted. The quoted initial costs for a range of sizes of bins are given in Table E-2. The average quoted price will be used for the purposes of this report. It was also estimated that the average

TABLE E-1 LIFE CYCLE COSTS - 25 CU. YD., FRONT LOAD PACKER

Year:	1	2	3	4	5
Capital Investment and Depreciation:					
Trade-in value (% of delivery price)	75	55	40	30	25
Investment, start of year ($)	68,000	51,000	37,400	27,200	20,400
Year-end value ($)	51,000	37,400	27,200	20,400	17,000
Yearly capital cost ($)	17,000	13,600	10,200	6,800	3,400
Debt Service and Insurance:					
Average yearly worth ($)	59,500	44,200	32,300	23,800	18,700
Yearly debt cost @ 12% ($)	7,140	5,304	3,876	2,856	2,244
Maintenance:					
Yearly estimated (% of delivery price)	4.5	6.5	10.5	16.5	22.5
Yearly estimated cost ($)	3,060	4,420	7,140	11,220	15,300
Fuel and Oil ($)	1,900	1,900	1,900	1,900	1,900
Downtime:					
Availability factor	95	94	91	88	85
Hours not available (1)	94	112	168	225	281
Cost @ $10/hr. for Reserve vehicle ($)	940	1,120	1,680	2,250	2,810
Obsolescence:					
Productivity factor	98	96	94	92	90
Extra hours required to match Production of new model(1)	37	75	112	150	187
Cost @ $10/hr ($)	370	750	1,120	1,500	1,870
Total Annual Cost ($)	30,410	27,094	25,916	26,526	27,524
Cumulative Vehicle Cost ($)	30,410	57,504	83,420	109,946	137,470

(1) Based on 36 hours/week

TABLE E-2

QUOTED PRICES FOR FRONT LOADED CONTAINERS

Container Size (Cu. Yd.)	Quoted Prices[1] ($)						Average Quoted Price ($)	Annual Cost[2] ($/Yr.)
2	186	300	296	---	198	241	244	38
3	259	335	375	---	268	---	309	48
4	293	390	417	454	319	355	371	58
5	335	570	---	---	355	---	420	65
6	424	600	514	514	386	461	483	75
8	496	735	635	---	463	518	569	89

(1) Prices quoted over the telephone by manufacturers; 8-13-79.

(2) Assuming a 9% minimum annual acceptable rate of return and 10-year usable life.

$$\text{Annualized Cost} = (\text{initial investment}) \times \frac{0.09\ (1 + 0.09)^{10}}{(1 + 0.09)^{10} - 1}$$

usable life of these type of bins is about ten years.

Roll-Off Container Commercial Refuse Collection System

Estimates for commercial collection using 20 to 40 cu. yd. roll-off type containers.

Equipment Costs

Based on estimates from two manufacturers, the approximate current (August 1979) initial costs for roll-off container collection equipment and expected usable life periods are as follows:

Hoist - $15,000 (10 yrs.)
Chassis - $46,000 (5 yrs.)

Tables E-3 and E-4 give the life cycle costs for the pieces of equipment.

The annual costs are as follows:

Hoist - $44,614/10 = $4,461/yr.
Chassis - $97,730/5 = $19,546/yr.
Total Annual Cost = $24,000/yr.

Labor

Assume same labor as previous section ($11.7/hr.; $24,300/yr.)

Roff-Off Containers

The average current price (August 1979) price for roll-off, open-top containers estimated by the manufacturers are as follows:

20 cu. yd. - $2,652
30 cu. yd. - $2,956
40 cu. yd. - $3,249
50 cu. yd. - $3,768

Assuming a minimum annual acceptable rate of return of 9% and a ten year expected usable life (suggested by manufacturers), the annual costs are calculated as follows:

TABLE E-3: LIFE CYCLE COSTS - HOIST FOR 20-40 CU. YD. ROLL-OFF CONTAINERS

Period (Years)	2	4	6	8	10
Capital Investment and Depreciation:					
Trade-in value (% of delivery price)	75	55	40	30	25
Investment, start of period ($)	15,000	11,250	8,250	6,000	4,500
Period-end value ($)	11,250	8,250	6,000	4,500	3,750
Period capital cost ($)	3,750	3,000	2,250	1,500	750
Debt Service and Insurance:					
Average yearly worth ($)	13,125	9,750	7,125	5,250	4,125
Yearly debt cost @ 12% ($)	1,575	1,170	855	630	495
Period debt cost ($)	3,150	2,340	1,710	1,260	990
Maintenance:					
Yearly estimated (% of delivery price)	4.5	6.5	10.5	16.5	22.5
Yearly estimated cost ($)	675	975	1,575	2,475	3,375
Period estimated cost ($)	1,350	1,950	3,150	4,950	6,750
Downtime:					
Availability factor	95	94	91	88	85
Hours not available(1)	188	224	336	450	562
Cost @ $2/hr. for reserve vehicle ($)	376	448	672	900	1,124
Obsolescence:					
Productivity factor	98	96	94	92	90
Extra hours required to match production of new model(1)	74	150	224	300	374
Cost @ $2/hr. ($)	148	300	448	600	748
Total period cost ($)	8,774	8,038	8,230	9,210	10,362
Cumulative vehicle cost ($)	8,774	16,812	25,042	34,252	44,614

(1) Based on 36 hours/week for two-year period.

APPENDIX F
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